climate ready regions

Deliverable Phase 2 – Climate risk assessment

Pernik Climate Risk Assessment for Action (PERNIKCLIMAACT)

Bulgaria, Pernik Municipality

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Document Information

Deliverable Title	Phase 2 – Climate risk assessment
Brief Description	This deliverable provides the refinement of the climate multi-risk assessment for the municipality of Pernik, developed using the CLIMAAX framework's common methodology for multi-risk assessment, i.e. two workflows - urban heatwaves and extreme precipitation. This refined CRA is founded on the initial CRA enriched through local data and knowledge from stakeholder engagement. The aim of the refinement, in addition to providing as thorough as possible data-driven analysis, was also to make sure the produced CRA offered a pragmatic, policy-oriented, and stakeholder-conscious reading of the results to enable the municipality to readily plug these into policy design and implementation plans.
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Abbreviations and acronyms

Abbreviation / acronym	Description
AR6	Assessment Report 6 from the IPCC
BAS	Bulgaria Academy of Science
CDS	Copernicus Climate Data Store
CoP	Community of Practice
CRA	Climate Risk Assessment
CRM	Climate Risk Management
CI	Critical infrastructure
DRMKC	Disaster Risk Management Knowledge Center
EEA	European Environmental Agency
IFP	Individual Follow-up Plan
IPCC	Intergovernmental Panel on Climate Change
NSI	National Statistical institute
NIMH	National Institute for Meteorology and Hydrology
NUTS	Nomenclature of Territorial Units for Statistics
RCP	Representative Concentration Pathways
PERNIKCLIMAACT	Pernik Climate Risk Assessment for Action

Executive summary

The present "Deliverable Phase 2 – Climate Risk Assessment" (CRA), developed under the project Pernik Climate Risk Assessment for Action (PERNIKCLIMAACT), constitutes the refined climate risk assessment for Pernik Municipality. The report describes the process through which the initial CRA, produced through the successful implementation of two CLIMAAX workflows based on European scale datasets – the urban heatwaves and extreme precipitation workflows, have been further enhanced through the incorporation into the analysis of local data and knowledge into the CLIMAAX framework of hazard, exposure, and vulnerability. The objective of this refinement was to increase accuracy, contextual relevance, and analytical robustness, while making the findings more operational and easier to translate into policy actions, including by non-specialist decision-makers.

The report begins by outlining the scope of the refined CRA, including its objectives, local context, governance arrangements, stakeholder participation, and risk ownership. Its primary purpose is to establish a scientifically sound basis for decision-making that is firmly grounded in local realities and responsive to stakeholder needs. In doing so, it aims to enhance and accelerate municipal planning related to climate adaptation and risk management, facilitate access to funding for adaptation measures, and strengthen coordination with regional actors. As the institution carrying principal responsibility for addressing climate risks, the municipality recognizes that its current capacity to manage their consequences remains limited. This consideration has been a key driver behind the implementation of PERNIKCLIMAACT, which seeks to advance adaptation as a more sustainable and cost-effective approach in comparison to risk management.

The report subsequently presents the results of the refined CRA. During Phase 2, the assessment focused on two interrelated goals: validating the outcomes of the Phase 1 workflows through stakeholder knowledge and locally available information; and improving those outcomes through greater precision and contextual detail. The findings generated during Phase 1 were largely confirmed, with locally available data and stakeholder knowledge testifying to the appropriateness of the European climate datasets for the assessment. At the same time, stakeholders stressed the importance of producing outputs that are more practical and directly applicable to local planning processes by non-expert policy-makers. To address this need, the analysis further refined the hazard, exposure, and vulnerability dimensions of both risks through the addition of locally specific data. For heatwaves, the inclusion of local data on vulnerability enabled a more targeted assessment of impacts and prioritization of adaptation efforts. For the extreme precipitation workflow, the enhanced assessment improved the analysis of workflow outputs by pointing to the more meaningful aspects of the projected shifts by layering local data on vulnerability that would enable the prioritization of adaptation actions in specific parts of the municipal territory.

The report also includes reflections on monitoring and evaluation, a roadmap for Phase 3 activities, and an overview of progress achieved thus far. Pernik Municipality considers the outcomes of Phase 2 to be of considerable value. The results provide a solid platform for the next stage of the project, during which key findings will inform updates to municipal strategic and planning documents and support stakeholder engagement efforts aimed at securing funding and improving coordination for adaptation measures. Beyond the analytical outputs themselves, the integration of local data into the workflows has continued to serve as an important capacity-building process for the municipality and strengthened institutional understanding of the CLIMAAX framework. Hence, this CRA approach is expected to deliver lasting policy benefits beyond the lifetime of the project.

1 Introduction

1.1 Background

Pernik municipality is a historically industrial and mining municipality, faced with complex climate-related challenges. It is among the most affected by the green transition due to its mining profile. Pernik deals with rising average annual temperature and heavy rainfall. Faced with complex climate challenges, we believe climate resilience requires a comprehensive approach based on strategic planning to optimize the impact of resources. The municipality is a member of the EU Mission: Adaptation to Climate Change and possesses a Municipal Climate Adaptation Strategy that will greatly benefit from a supplementing and upgrading climate risk assessment to be developed under CLIMAAX.

Pernik municipality is located in "South and South-Western Bulgaria" (NUTS1), “South-Western Planning Region” (NUTS2). It spans over an area of 484.2 sq. km, placing it among the medium-sized municipalities in the country, with population size of 81170 as of December 2024 and 24 settlements, including 2 cities - Pernik and Batanovtsi. The Municipality is located in the temperate continental climate zone of Bulgaria, including its mountainous variation on the slopes of the surrounding mountains. The average altitude of the municipal territory is about 750 m with variations between 600 m and over 1600 m above sea level. Due to local physical and geographical features, temperature inversions are present, which in combination with the predominance of calm weather premise the increase in the concentration of pollutants in the ground air layer.

1.2 Main objectives of the project

PERNIKCLIMAACT is a project designed to deliver a refined climate multi-risk assessment for the Municipality of Pernik and plug it into existing and future strategic climate action documents for evidence-based policy-making and fund-raising for climate change adaptation measures. Within the project, the Second Phase is paramount as its primary aim is the development of this refined multi-risk climate assessment. In doing so it builds upon the outputs generated through the CLIMAAX workflow and enriches them with local knowledge and data. This second phase is thus key in ensuring that the final Climate Risk Assessment (CRA) is as practical, comprehensive, and useful as possible for the municipal administration and decision-makers. Therefore the CRA refinement during Phase 2 is decisive for the transition from analysis to policy that is foreseen in the next project stage.

The Second Phase thus seeks to improve the accuracy, depth, and accessibility of the analysis for local policy-makers and practitioners, while also strengthening the sense of ownership among institutions, civil society actors, and residents. The methodology and findings developed during this stage have already supported, and will continue to support, extensive stakeholder engagement activities. These consultations have contributed to shaping the assessment into a tool that can effectively guide the next steps, including the revision and enhancement of the Municipality of Pernik’s Climate Change Adaptation Strategy, adopted in September 2024, as well as its supplementation with an implementation action plan.

The integration of detailed local information in phase 2 has not only confirmed and strengthened the validity of the workflow outputs by combining a scientifically grounded and methodologically coherent process combining analytical tools with localized data but has also contributed to greater precision, validation, and detail. It has also hence made the assessment more relevant and practical for advocating for national funding opportunities and attracting investments for climate adaptation initiatives. The added value generated during this phase, made possible by the strong analytical basis and methodological structure provided by the CLIMAAX framework and the workflow outputs, will also support the municipality in promoting a more effective regional approach to climate risk planning and disaster prevention with regional authorities.

The climate multi-risk assessment will enable the municipality to upgrade its Municipal Climate Adaptation Strategy. It will inform the municipal action plan in implementation of the strategy, it will enable the municipality to better tailor climate change adaptation measures and combine them in a mutually enhancing way with efforts for the green transition of the region. The risk assessment will serve as the foundation for climate action policies in the municipality and will help it adapt its approach for effective climate change adaptation and disaster prevention. By improving the municipal understanding and evaluation of the climate risks, the study will also equip the municipality with the knowledge and evidence to request and attract public and private funding and investments in climate change adaptation efforts in the municipality. It will also enable the municipality to contribute to regional coordination and planning efforts in disaster prevention and early warning by working jointly with regional authorities and using the study results and methodology. The study will also allow the municipality to better communicate the climate risks to residents to build ownership and support for adaptation measures, as well as to tailor solutions in favor of disproportionally affected segments of the population to ensure climate justice. Thus, the study will enhance multi-stakeholder engagement, which will be carried both directly and through mediators, such as the media and civil society organizations to reach all relevant stakeholders.

1.3 Project team

The project team consists of two groups: a municipal team of three employees appointed by the mayor and a subcontracted team of external experts. Both teams work in close coordination, following the Work Plan in the Individual Follow-up Plan (IFP). The municipal team ensures communication with the administration, provides information and feedback to the experts, monitors the quality and timely delivery of activities, and promotes knowledge sharing and capacity building across departments. The external experts support the municipal team by carrying out assigned tasks and deliverables as specified in the project's IFP. They provide the essential technical and expert input required for the implementation of the PERNIKCLIMAACT - capacities that would not have been available within the municipality without the CLIMAAX support.

1.4 Outline of the document's structure

The central element of this document is the refined Climate Risk Assessment (CRA) for Pernik Municipality, developed as the Phase 2 deliverable of the PERNIKCLIMAACT project in accordance with the CLIMAAX methodology (Section 2). The section starts with an overview of the CRA scoping process, presenting its objectives, governance structure, contextual considerations, and stakeholder involvement. It proceeds with an assessment of climate-related risks through the integration of CLIMAAX workflow results and locally sourced data, enabling a more detailed analysis based on the interconnected dimensions of hazard, exposure, and vulnerability. Building on these refined findings, the document further evaluates the severity and urgency of identified risks, examines adaptive capacity, and reflects on monitoring, evaluation outcomes, and lessons learned, while also outlining the work plan for the next phase of the project. Section 3 summarizes the principal conclusions and most important findings, whereas Section 4 reviews project progress through milestones and key performance indicators. Supporting materials and references are included in Sections 5 and 6.

2 Climate risk assessment – phase 2

2.1 Scoping

2.1.1 Objectives

This refined CRA is to serve multiple key purposes for the municipality that have not changed since the scoping for Phase 1. At its core, it seeks to deepen the understanding of the two priority climate risks - urban heatwaves and extreme precipitation - that currently have a significant impact on the municipality. By analyzing both the present conditions and future projections, thereby utilizing local data and knowledge, the refined CRA is intended to act as a foundation for designing adaptation measures that address current vulnerabilities while also anticipating future challenges. On one level, the refined CRA clarifies the municipality's existing exposure and sensitivity to these two risks, helping to shape immediate adaptation responses. Simultaneously, it aims to highlight how these risks are expected to evolve over time, enabling policy-makers to implement proactive and well-coordinated measures that are timely and consistent. A crucial aspect of this CRA is its commitment to presenting evidence-based, methodologically sound findings in a format accessible to political leaders and local decision-makers, thereby ensuring the outcomes are not only technically reliable but also actionable.

By offering a scientifically grounded framework, the refined CRA is positioned to support informed political choices and guide the practical selection of technical climate adaptation solutions across various domains, such as prevention, civil protection planning, and emergency response. It will directly inform an update of Pernik Municipality's Strategy for Climate Change Adaptation (2024) and present the foundation for its associated action plan. This includes laying the groundwork for attracting investment and funding to implement adaptation measures. The CRA will also provide the evidentiary basis for justifying selected approaches, helping to secure alignment between strategy, implementation, and long-term policy direction in building local climate resilience. Beyond its use at the municipal level, the CRA is also intended to support Pernik in advocating for adaptation measures at the regional and national scale. It strengthens the municipality's case for funding by underscoring prevention as a cost-effective and environmentally sound path forward.

Prior to joining the CLIMAAX project, Pernik faced considerable obstacles in producing a CRA. These included a lack of internal expertise, insufficient funding for external support, and most importantly - the absence of a reliable and standardized methodology that would ensure high-quality analysis comparable across EU municipalities. The CLIMAAX project helped to bridge these gaps - bringing in necessary technical support, providing a robust methodological framework, and offering tools to align scientific depth with policy relevance. In particular, the CLIMAAX workflows addressed a recurring challenge the municipality had struggled with: making use of available European datasets while also identifying, refining, and integrating local data. The framework now enables the team to better evaluate what data is most useful and how it can be applied for clearer insights.

In Phase 2, the CLIMAAX framework has been crucial in guiding the municipality in selecting and vetting the local data and knowledge needed for the utilized workflows to be refined and hence has tremendously helped it to overcome the challenge of lacking readily available local data.

2.1.2 Context

In September 2024, Pernik Municipality took a major step toward climate resilience by adopting its Municipal Climate Adaptation Strategy. This document - developed by an external team - relies on a combination of European and national data sources, including the IPCC's 2022 Sixth Assessment Report, the DRMKC Risk Data Hub, Copernicus C3S Atlas, Bulgaria's National Institute of Hydrology and Meteorology (NIMH), the Bulgarian Academy of Sciences (BAS), and the Climate-ADAPT platform. It stands as the municipality's primary strategic instrument for adapting to climate change impacts at the local level.

Historically, the municipality's actions in response to climate risks have been reactive - primarily addressing events after they occurred rather than preventing them. Due to a lack of predictive data and strategic direction, adaptation efforts were piecemeal and underfunded. Although the national framework in Bulgaria tasks municipalities with prevention and coordination duties, it does not provide dedicated funding or expert support for the development of local CRAs. This leaves municipalities without the tools needed to implement meaningful, forward-looking climate action, effectively making national strategies difficult to translate into local practice.

To address these long-standing challenges, Pernik turned to the CLIMAAX project. The initiative fills critical gaps in expertise, funding, and methodology, equipping the municipality with a reliable framework for conducting a robust, multi-risk climate assessment. The resulting refined CRA will form the analytical backbone of the adaptation strategy, informing both its update and the creation of a concrete action plan for its implementation.

This pivot toward a more strategic and proactive climate agenda was driven by the mounting urgency of climate-related hazards and the municipality's growing recognition of its leadership role in local adaptation and prevention. In response, Pernik became part of the EU Mission: Adaptation to Climate Change, independently developed its initial adaptation strategy, and sought support through CLIMAAX to produce the in-depth CRA it previously lacked.

With this CRA, the municipality gains more than a technical report - it acquires a powerful tool to influence policy and funding at multiple levels. Locally, it strengthens planning and improves the targeting of adaptation measures. Regionally and nationally, it positions Pernik to advocate for coordinated adaptation efforts and attract investment. Though Bulgaria has a national adaptation strategy (developed with the World Bank in 2019), the absence of local implementation mechanisms severely limits its impact. Pernik's CRA seeks to bridge that gap by grounding adaptation efforts in actual local risks, vulnerabilities, and capacities.

Several economic sectors and systems - such as tourism, healthcare, public infrastructure - face growing threats from climate-related hazards. While the municipal adaptation strategy already proposes actions for the near and medium term, the CRA will strengthen this framework by offering deeper insights into the risks and their projected evolution. It will also enable the municipality to refine, prioritize, and, where necessary, expand its set of adaptation measures to ensure they are both effective and evidence-based.

2.1.3 Participation and risk ownership

The responsibility for identification, assessment, and mitigation of specific risks, including climate risks, rests with the municipal government. Under Bulgaria's Disaster Protection Act (National Gazette, 2016), the municipality - led by the mayor - is legally accountable for drafting and executing action plans for response to disasters. This mandate also extends to preventive and risk reduction planning, including climate change adaptation as a forward-looking form of disaster prevention. While the Ministry of Interior offers some support in civil protection during emergencies, municipalities receive little or no assistance when it comes to long-term prevention and climate adaptation planning. The absence of guidance or resources for proactive adaptation work underscores a significant gap in institutional support. When disasters, such as extreme precipitation strike, the financial and operational capacity of the municipality is quickly overwhelmed, necessitating assistance from higher levels of government. This reality highlights the importance of adaptation and preventative approaches - not only to protect lives and infrastructure, but also to conserve limited local resources. The municipality intends to use the CRA to identify which adaptation measures would be most effective in decreasing extreme precipitation flood risks over the long term. Likewise, as heatwaves become more frequent and severe - and with an aging population particularly at risk - the CRA will help pinpoint vulnerable zones and timeframes where targeted interventions, such as cooling strategies or healthcare responses, can reduce population exposure and improve resilience.

The main stakeholders and beneficiaries, identified as early as the stage of the IFP and confirmed during the scoping for Phase 1, are first and foremost municipal residents and private business, who will benefit from the policies and measures that the study will enable in adaptation to climate change that will decrease the damages to property and health risks; the municipal leadership and administration, who will be able to base policies and projects on a sound evidential basis to adapt to climate change and to prevent disasters; and municipal structures whose work will be made easier and more effective; the local and regional authorities responsible for prevention and early warning as the municipality will share the results from the study and this knowledge will help better plan and coordinate preventive and responsive measures in the entire region; and last but not least – national authorities and respective public administration structures who will benefit from Pernik's experience to model objectives and expectations for municipalities at large, methodology and approach. Additional relevant stakeholders are local and regional media that are seen rather as partners in dispersing information.

In respect to priority and vulnerable groups engagement, upon the completion of the first phase of the CRA, Pernik has been actively sharing the results and seeeking feedback from these groups through ad-hoc and planned bilateral and multilateral meetings. The municipality has also organized a consultation meeting with local residents and other stakeholders to share the results and request input to granulate the analysis. Simultaneously, public communication has aimed to build local awareness and encourage community participation in adaptation initiatives.

During Phase 1, outreach was limited to select stakeholders to gather input on climate-related risks and is therefore not part of the project KPIs and milestones. It was mainly targetting municipal officials and professionals from municipal and regional structures of national agencies and ministries relevant to disaster response, environmental protection, healthcare, and regional development, and representatives of vulnerable communities due to their potential knowledge of risk impacts and exposure. Stakeholder engagement on broader terms based on CRA results was planned purpusofuly by the municipality for Phases 2 and 3 as the CRA results are intended to serve an excellent foundation to generate interest and build understanding in the otherwise difficult-to-communicate topic of climate change. This strategy has proven successful so far in Phase 2 as the concrete results and analysis of the CRA have made discussions considerably easier and the topic much more palpable especially for residents, including priority and vulnerable groups.

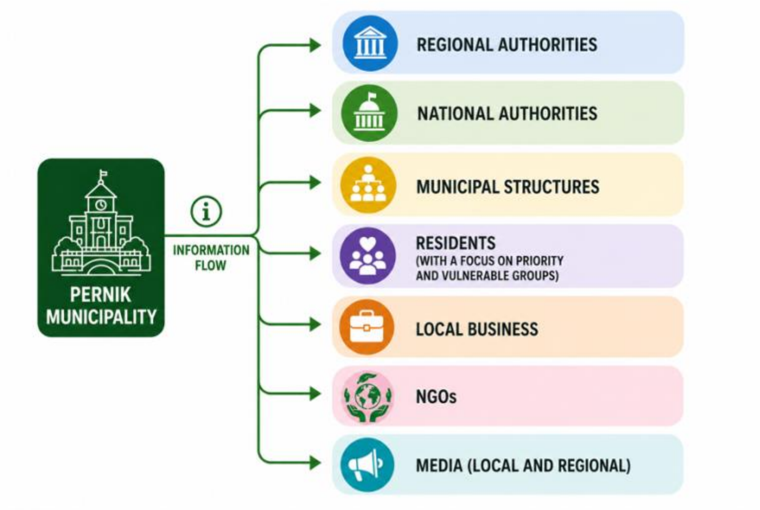

Figure 2-1 Stakeholder engagement and information flow

Upon the successful completion of Phase 2, engagement with regional institutions and national agencies, will aim to foster better coordination on climate risk prevention and emergency preparedness. Outreach to national policymakers will focus on advocating for funding and encouraging broader adoption of the CRA methodology across other municipalities in Bulgaria.

2.1.4 Application of principles

The project has incorporated the principle of social equity, justice and inclusivity through an inclusive approach and continuous engagement with relevant stakeholders that has started as early as the scoping step of Phase 1 and continued systematically during Phase 2. Active stakeholder involvement has been a central component of the project of particular importance as a tool to balance the shortcomings of limited local climate data. In this context, stakeholder contributions, validation, and a sense of shared ownership are essential for the effective delivery of the project and for ensuring that its findings translate into practical policy outcomes. The two priority risks identified in the CRA both contain important social dimensions: age-related vulnerability in the context of urban heatwaves, and unequal distribution of impacts linked to the location of residences, workplaces, and businesses in the case of extreme precipitation. A fair and inclusive approach to strengthening local climate resilience was embedded throughout the CRA process by ensuring that these affected population groups were represented during the scoping and risk assessment stages, alongside a multi-stakeholder process for reviewing, validating, and finalizing results and future actions.

The quality and rigour of the analysis were secured through the consistent application of the CLIMAAX framework and workflow methodology. The team remained fully dedicated to both the analytical principles and operational approach provided by the CLIMAAX methodology, which offers a high standard of scientific rigor while also supporting policy-relevant and practical outputs. at the same time a central objective of stakeholder engagement was ensuring the transparency of the process for generating the CRA. Throughout the project, strong local ownership of both the process and the analytical tools was established. Significant efforts were also made to enhance transparency by integrating locally sourced data and contextual knowledge, thereby improving the granularity, accuracy, and practical relevance of the assessment for local stakeholders, especially decision-makers and policy practitioners.

A precautionary approach toward local data has guided the analysis, both in regard to climatic conditions and non-climatic factors. Particular effort has been made to make sure the selected data fits the framework of the analysis and sustains a coherent and policy-oriented analysis of the workflow results. Particular attention has been given to the relevance and suitability of the selected data in order to ensure that they adequately support the analytical framework adopted within the CRA. This was especially important given the varying availability, resolution, and reliability of local information sources, as well as the need to combine data originating from different institutions and sectors. The project team sought to ensure that all data incorporated into the assessment contributed meaningfully to the analysis of hazard, exposure, and vulnerability, while avoiding the inclusion of information that could distort or complicate the interpretation of the workflow outputs. At the same time, efforts were made to maintain consistency between locally collected information and the methodological requirements of the CLIMAAX framework. The selection and utilization of local data were therefore guided not only by availability, but also by the objective of producing a coherent, transparent, and policy-relevant assessment. This approach ensured that the refinement of the workflow results strengthened the analytical robustness of the CRA while also increasing its usefulness for decision-makers, planners, and other stakeholders involved in climate adaptation and risk management. By grounding the analysis in locally relevant evidence and applying a cautious and methodical approach to data integration, the municipality has been able to develop findings that are both scientifically credible and directly applicable to future policy development and adaptation planning.

2.1.5 Stakeholder engagement

Throughout Phase 2, the project team sustained and further developed its stakeholder engagement activities. Bilateral communication and ad hoc meetings were continued with municipal and regional experts, as well as with groups from the local population that are disproportionately affected by climate-related risks. These exchanges were particularly important when decisions were being made regarding the selection, interpretation, and application of local data within the CRA process.

In parallel, the team engaged the broader local public through a public consultation event during which the results from Phase 1 were presented for discussion and feedback. The presentation concentrated primarily on the key findings and outputs rather than on technical methodology or data processing, as the target audience consisted mainly of non-specialists. The intention was to communicate the practical relevance of the assessment, validate the findings through public feedback, and demonstrate how the CRA can support future adaptation efforts at community level. The consultation process generated useful input in several ways. On one hand, it confirmed the validity of the analysis, as no major inconsistencies or contradictions with the workflow outputs and conclusions were identified. On the other hand, participants highlighted areas where additional detail and refinement would be most valuable. One of the main conclusions emerging from the discussion was the strong need for more detailed local data about identified locations that should be prioritized for adaptation interventions. Consequently, the project team devoted additional effort to incorporating detailed local data related to hazards, vulnerability, and exposure, including information of local vulnerable locations, demographic information, and infrastructure condition data. The project results are expected to directly affect the daily lives of many consultation participants, who are anticipated to benefit from future adaptation measures that will be prioritized and implemented using both municipal resources and external national or EU funding, guided by the findings of the CRA.

One of the main challenges encountered in stakeholder engagement to date has been the necessity to translate technical outputs and analytical findings into language that is understandable, relatable, and actionable for non-expert audiences. To address this challenge, the team has consistently worked to strengthen the practical and policy-oriented dimensions of the analysis so that stakeholders can more easily recognize its relevance, added value, and real-world implications. This approach continues to guide the refinement of the CRA and the overall stakeholder engagement strategy.

Upon confirmation of Deliverable 2, the team has planned a series of three online publications accompanied to communicate the main conclusions of the refined CRA more broadly through social media channels. These publications will focus on explaining the practical benefits and advantages that the assessment can provide to the local population. In addition to the local community, another important target audience includes regional and national institutions. The project team intends to contact these stakeholders formally through official correspondence presenting information about the CRA process and results, with the aim of encouraging replication of the approach and facilitating future exchanges of knowledge and experience. Information and project outcomes will also be disseminated to other Bulgarian municipalities through the network of the National Association of Municipalities in Bulgaria. This outreach will not only communicate the project's findings and benefits, but will share practical know-how on how municipalities can apply the CLIMAAX methodology where in-house resources are sufficient.

2.2 Risk Exploration

2.2.1 Screen risks (selection of main hazards)

During Phase 2, the Municipality of Pernik did not modify the number of priority risks selected for the CRA, namely extreme precipitation and urban heatwaves. The decision was based on municipal estimations – namely the magnitude and managability of these two risks that constitute significant burden on the municipality, as well as on feedback received from stakeholders throughout the risk assessment and prioritization process.

In line with the workflow structure, the CLIMAAX methodology, and the analytical framework based on hazard, exposure, and vulnerability, in Phase 2 the team succeeded in collecting, selecting, analyzing, and integrating local and regional data that significantly enhanced the level of detail and granularity of the outputs produced under Deliverable 1. Since the completion of the initial risk screening for the CRA, no substantial changes have occurred regarding the elements included in the screening process. Consequently, the original risk screening information presented in Deliverable 1 remains fully valid and applicable for Deliverable 2 as well.

The Municipality of Pernik has been experiencing a multitude of climate-related hazards, including urban heatwaves, extreme precipitation, droughts, and river flooding. Among these, heatwaves and extreme precipitation have been identified by means of institutional knowledge (from historical observations, recent events, and a record of utilized municipal capabilities) and stakeholder validation - as the most pressing risks due to their severity, considerable impact and lack of municipal capabilities to act in adaptation and prevention. These two hazards not only pose direct risks but also act as catalysts for additional hazards, such as droughts and river flooding. Both are further exacerbated by non-climatic factors, particularly inefficient response and prevention efforts management at both state and regional levels, and the health profile and demographic structure of the population in Pernik municipality. Given these considerations, the municipality has prioritized these two hazards and the associated risks for assessment under the current CRA.

Pernik has experienced a series of urban floods directly linked to the impacts of climate change as manifested in extreme precipitation. Rainfall has increased from 562,7mm to 644,8mm since 1979 and sudden torrential rains cause floods that damage people's homes, local infrastructure, and local businesses. Thus, for instance, in November 2023 during an extreme precipitation event, the rainfall for 12hours equaled the usual amount for one month. Two other recent examples include torrential rain floodings from the beginning of October 2024 when a rainfall of approximately 40l/sqm flooded parts of the city of Pernik and from April-May 2025 that resulted in power outages, property damages, and infrastructure damages, including a collapsed retaining wall in one of the residential areas that was cause for the mayor to announce partial state of emergency. The damages caused present an existential challenge to the municipality and its residents as these require substantial funds to recover. Heavy rainfall also periodically creates risks of overflow of the Struma river, which runs through a considerable part of the residential areas in the municipality. The city of Pernik is classified in the National Flood Risk Management Plan as a high risk area. Additionally, due to the increasing average annual temperatures the period of snow melting starts earlier and the risks of floods from the river starts as early as December. Floods as a result of heavy rainfall are increasingly common in spring and autumn, and damages caused present an overwhelming challenge to the municipality and its residents as these require substantial funds to recover.

The Municipality of Pernik suffers from increasing average annual temperature, which has risen by 1.5% since 1979. In the summer months there are frequent heatwaves that pose a threat to human health. These are exacerbated by the industrial profile of the municipality as pollution is frequent and the increase in fine particulate matter also enhances the negative impact of heatwaves. Heatwaves in the summer can begin as early as June and continue throughout August, posing risks to the health of the increasingly aging population, as well as creating risks for fires. For example, in July 2024 a large forest fire raged next to the Rasnik village in the municipality causing considerable damage and all settlements in the region were instructed to create disaster response volunteer units. The frequent pollution and increased levels of fine particles in the air from the coal industry also contribute to heatwaves.

Knowledge on the selected climate hazards for this CRA is mainly based on histrorical observations and pan-European ready-to-use data and instruments. The municipality, prior to joining CLIMAAX, did not have the capability to identify and operationalize to a sufficient degree available regional or local data and hence use it for decision-making. This has now occured in Phase 2 of the project in a targetted manner using the workflow methodology as a guide as to what data to seek to enhance its granularity.

Pernik is also historically a mining region that needs to be transformed and transition from coal mining and coal-based production of electricity to renewable energy sources and a more environmentally sustainable economic profile. Given that climate risks are intertwined with the negative environmental effects of mining and coal electricity production, we believe that the solutions we find to these two clusters of challenges should be mutually enhancing. Climate adaptation solutions should contribute to the green transformation of the region and the green transition should be planned in ways to contribute to climate change adaptation and prevention of climate-induced disasters. The municipality is among those that qualify under the Just Transition Fund for support. A comprehensive climate multi-risk analysis will not only help us plan impactful adaptation measures, adapt our strategy, and prevent disasters and threats to human health and wellbeing, but will enable us to coordinate these solutions with measures related to the green transformation. CLIMAAX has provided us with the methodology, the tools, and the structure to make sure we have a deep understanding of the climate risks that impact the municipality and the region. It has allowed us to contract the needed external help to base the analysis on expert knowledge. Thus, with CLIMAAX, we has been closing the knowledge and funding gap that we previously experienced and which prevented us from conducting a climate risk assessment. Once we have a climate risk assessment, we are confident, this will help us not only to plan concrete climate adaptation measures but also attract the necessary funds to implement them. Being able to learn from CLIMAAX experts and the community of other municipalities that employ the same methodology is particularly important for the municipality. Given the complexity of the climate-related challenges faced due to the specific profile of the municipality, it needs and is eager to learn from the best European practices.

2.2.1 Choose Scenario

For the two priority risks - urban heatwaves and extreme precipitation - a multitude of climatic and socio-economic developments have been taken into consideration to produce a sound foundation for the risk analysis.

In the urban heatwaves hazard assessment workflow, two climate change scenarios - RCP4.5 (representing a medium emissions pathway) and RCP8.5 (representing a high emissions pathway) – have been used to evaluate how future climate conditions may influence the frequency of heatwave events. The hazard assessment component, aligned with EU-wide health-based thresholds as defined in the EuroHEAT project, has provided projections of heatwave frequency for the period 1986-2086 under both climate scenarios for the selected area. For the Municipality of Pernik, the chosen risk assessment workflow has estimated heatwave risk by combining high-resolution surface temperature data with information on the spatial distribution of vulnerable population groups. This approach has enabled the identification of areas where exposure and vulnerability intersect, offering a robust estimate of both current and future risk levels. The integration of these hazard and risk assessment workflows provides a comprehensive basis for understanding the evolving heatwave risk landscape.

However, it is essential to consider non-climatic contextual factors that may exacerbate future vulnerabilities. Notably, demographic projections indicate a continuing trend toward population aging in the region. In parallel, national healthcare reform strategies, which aim to consolidate services by closing smaller, underperforming municipal health facilities, may further limit local access to care during extreme heat events. Another non-climatic challenge for the municipality has been the proximity to the capital city, which has been economically tempting for younger generations to relocate for career purposes. However, the municipality has been trying to turn this into an advantage whereby due to good living conditions in Pernik, commute would be a viable and preferable option for people working in the capital. Climate adaptation and green transformation are vital to turn the city and municipality of Pernik into a prefered livigng location by balancing out the consequneces of both climate change and the negatives of the coal-mining profile of the region.

In the extreme precipitation workflow for the hazard we use a baseline and a future scenario to utilize CDS data, i.e. the timespan 1976-2005 represents historical simulations, while the period 2041-2070 is used for climate projections, whereby a specific combination of General Circulation Model (GCM), Regional Climate model (RCM), and a Representative Concentration Pathway (RCP) is selected. In the hazard workflow we look at the historical data scenario and the future projections under RCP8.5. For this later scenario we look at two plots: the precipitation for 24h with a 10-year return period and the relative change to the baseline of the historic period for a 24h precipitation with a 10-year return period. The hazard workflow also gives us mean precipitation for 24h duration events in Pernik municipality for the historical and the RCP8.5 scenarios, which is important in respect to the non-climatic factors related to drainage capacity planning.

In the extreme precipitation risk workflow the municipality again looks at the same historic and RCP8.5 scenarios and seeks to plot the shift in frequency of extreme precipitation events for its defined critical impact-based rainfall threshold for the span 2041-2070 and analyse the juxtaposition between the frequency in the current return period and the expected return period for RCP8.5, as well as plot the relative change in magnitude for the threshold under RCP8.5 with a fixed frequency for period of 2041-2070. The risk workflow takes into consideration non-climatic elements that are incorporated in the critical impact-based rainfall thresholds, namely the capacity of drainage systems and local infrastructure to withstand certain levels of impact from extreme precipitation, which constitute the exposure and vulnerability elements. These scenarios have been applied with the threshold of 35mm in 24 hours with a frequency of 3 years to the municipality of Pernik and the city of Pernik.

2.3 Regionalized Risk Analysis

2.3.1 Hazard #1 - fine-tuning to local context: Urban heatwaves

Table 2-1 Data overview workflow #1 Urban Heatwaves

Hazard data	*Vulnerability data*	*Exposure data*	*Impact metrics/Risk output*
EuroHEAT project CDS dataset	*WorldPop data (DOI: 10.5258/SOTON/WP00646) for most vulnerable groups of the population, age structures of 2020*	*RSLab Landsat8*	*Risk map plotting the possible heat risk level to vulnerable population.*
average monthly temepratures from NIMH measuring; *NIMH analysis on hot days;* *NIMH analysis of regional air temperature anomalies.*	*Critical vulnerable places based on local knowledge – sites of higher social concentration or importance, especially in respect to vulnerable groups*		*Increased granularity of plotted risk map in respect to vulnerability*

2.3.1.1 Hazard assessment

During the computations for Phase 1, the team used the hazard workflow relying on EuroHEAT CDS data and it evaluates the projected impact of climate change on the frequency of heatwaves in the municipality of Pernik, considering both the RCP4.5 and RCP8.5 climate scenarios. This assessment relies on a CDS dataset provided by the EuroHEAT project, which offers high-resolution data on a

12x12 km grid across the entire European Union, spanning the years 1986 to 2085. Due to the absence of a nationally established definition for heatwaves for the EuroHEAT project, the methodology adopts the EU-wide health-related criteria to ensure consistency and comparability.

For the purposes of the initial Climate Risk Assessment (CRA), the analysis focused on the months of June through August, which were recognized as the hottest months of the summer season. Within this framework, heatwaves are characterized as events lasting at least two consecutive days during which both the maximum apparent temperature (Tappmax) and the minimum temperature (Tmin) exceed their respective 90th percentile thresholds for each month. This dual-threshold approach ensured a comprehensive representation of heatwave conditions by accounting for both daytime and nighttime temperature extremes. The results, presented in Figure 2-1, illustrate the anticipated annual frequency of heatwaves under the two climate change scenarios, highlighting a clear upward trend in heatwave occurrence over time. These projections provide crucial information that enables the municipality to better understand the evolving risks associated with extreme heat events and to develop targeted strategies for climate adaptation and public health protection in response to these emerging challenges.

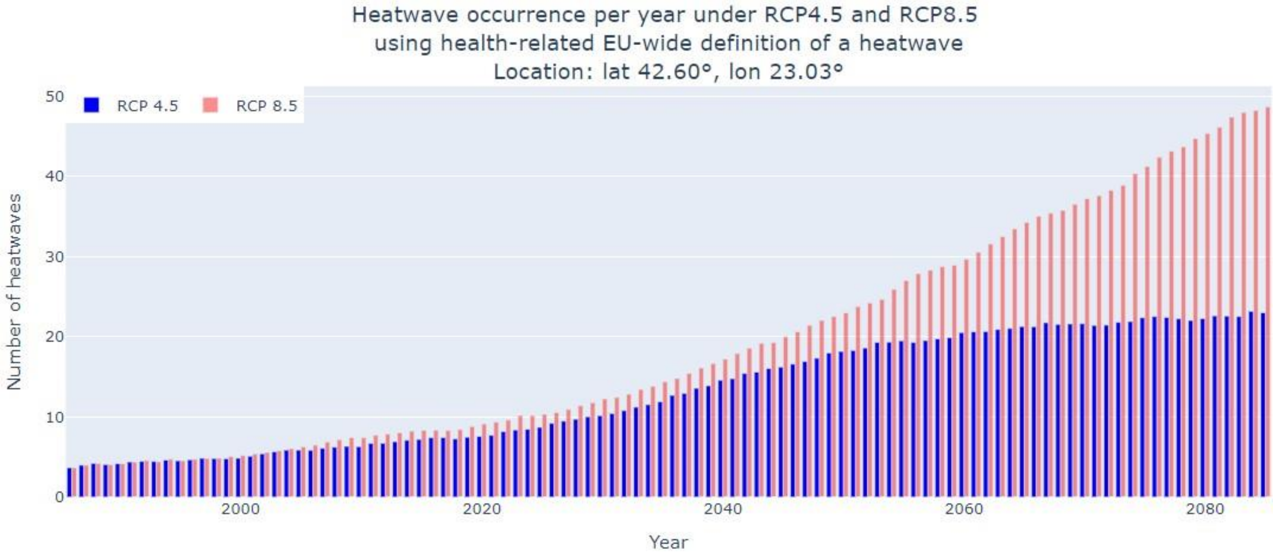

Figure 2-2 Heatwave occurrence per year under RCP4.5 and RCP8.5 using health related EU-wide definition of a heatwave for the location of Pernik

In Phase 2, the team further developed the outputs of the urban heatwave workflow from Phase 1 through three complementary lines of analysis. First, the team sought to find average monthly temepratures from NIMH measuring to confirm the months analysed with the workflow based on satellite data. Secondly, once this was confirmed, we turned attention to the national definition of "hot days," which applies a threshold of maximum daily temperatures above 32°C. Based on archival and recent data published by the National Institute of Meteorology and Hydrology (NIMH), the team examined whether there is a discernible long-term trend in the annual number of such hot days. According to the NIMH Annual Hydrometeorological Bulletins for the period 2019–2024, areas situated below 1000 meters altitude, which is the case with Pernik municipality located at 710m altitide, show a steady increase in the number of hot days, estimated at approximately 0.4 additional days per year (National Institute of Meteorology and Hydrology, 2025). At the same time, information contained in both the annual and monthly NIMH bulletins concerning regional air temperature anomalies indicates that the Pernik region, within which the Municipality of Pernik is located, has experienced an increase of approximately 2–3°C in average annual temperatures. This data again confirms the direction of conclusions provided by the hazard workflow, namely - the growing intensity of the hazard under present-day climate conditions. Thus, by combining the workflow outputs with the available historical and regional climate trend data by the NIMH, the team was able to validate the findings of the assessment. Simulatenously, seeing how the analysis corresponded to local data the team strengthened its understanding of the urban heatwave hazard under the current climate scenario, which contributed to a very pragmatic, hands-on approach and increased motivation in respect to translating CRA results into policy.

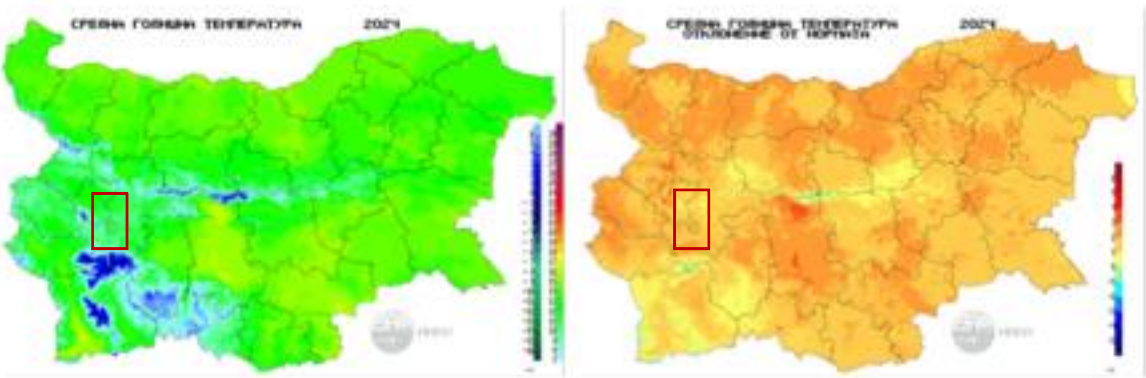

Figure 2-3: Average annual temperature on the left map and deviation from the norm on the right map, Source of the graphic: NIMH, Annual Bulletin, 2024, the graphic has been altered to add rectangular emphasis on the territory of Pernik municipality

2.3.1.2 Risk assessment

The CLIMAAX risk assessment workflow utilized by the Municipality of Pernik in Phase 1 is grounded in historical satellite-derived data. Fundamentally, this approach involved overlaying maps of overheated areas - derived from land surface temperature satellite imagery - with population density maps highlighting vulnerable groups, specifically children under five and elderly individuals over 65 years of age. This integration generates a 10x10 risk matrix that forms the foundation for developing a comprehensive heat risk map, illustrating the level of heat exposure faced by vulnerable populations. In implementing this workflow, the municipality has utilized RSLab Landsat 8 data (incorporating MODIS emissivity) to analyze surface temperatures across a polygon encompassing its territory. The focus has been placed on the largest urban areas, deliberately excluding smaller settlements and forested regions that are less susceptible to heatwave impacts. This dataset has provided critical exposure information for the risk analysis. Vulnerability data, reflecting the density of at-risk population groups, was sourced from the WorldPop dataset and incorporated into the risk map generated by the workflow. This combined analysis has enabled the Municipality of Pernik to pinpoint locations where heat exposure is most pronounced and where vulnerable populations are most concentrated. Because of the limited spatial resolution of the vulnerable population density data, the interactive risk map proved instrumental in enhancing the municipality's ability to identify high-risk areas by providing the possiblity to zoom-in. The integration of more localized data in the Phase 2 has further mitigated this challenge.

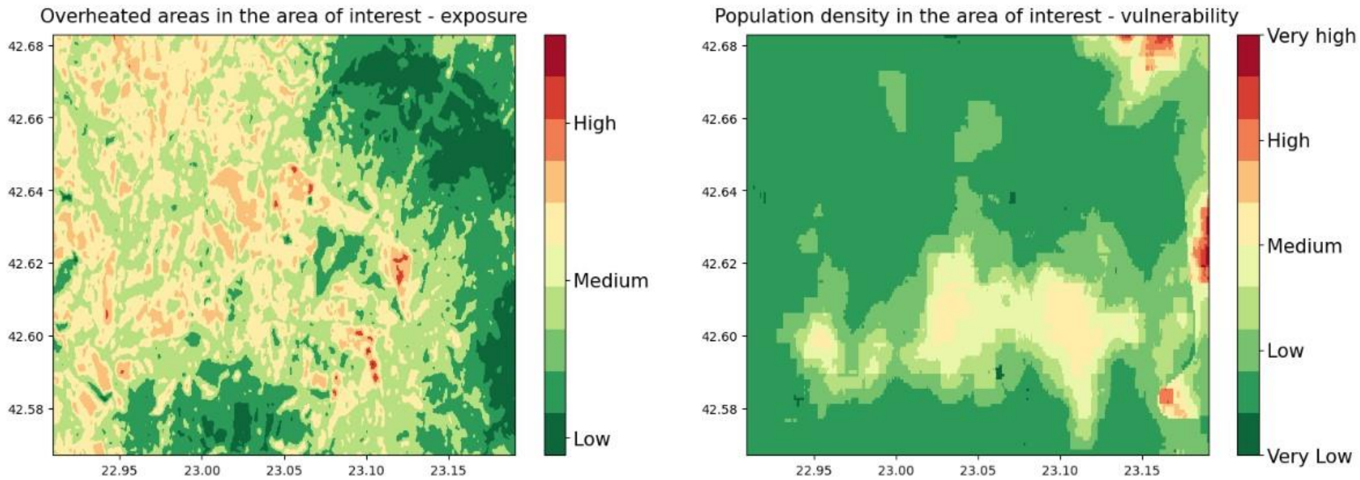

Figure 2-4 Maps of overheated areas (exposure) and population density (vulnerability) in the Municipality of Pernik

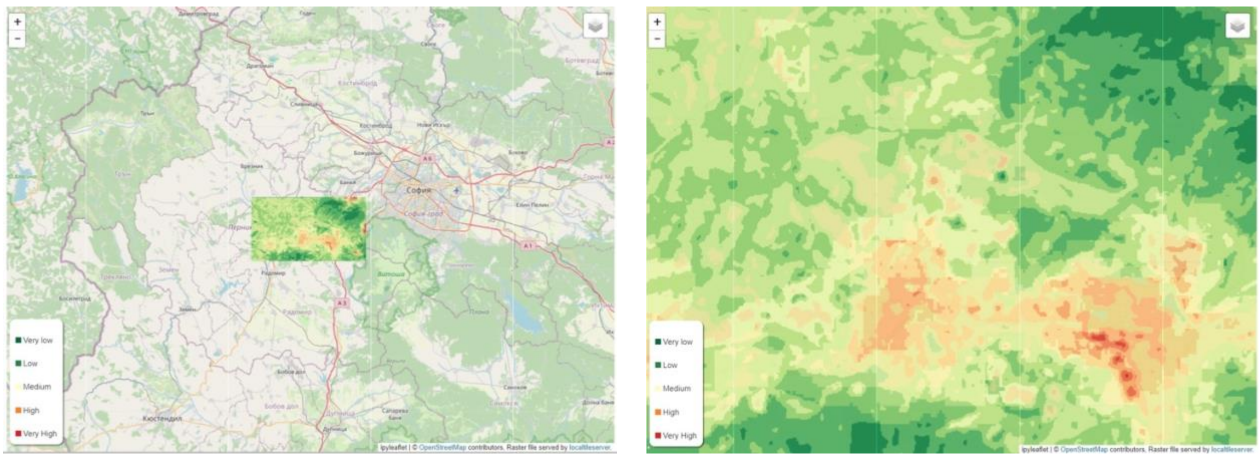

Figure 2-5 Heatwave risk to vulnerable population in the Municipality of Pernik to the left, zoomed version to the right.

Therefore in Phase 2, the team sought to address the limitations associated with the relatively coarse resolution of population density data available at the European level. Building upon the risk hotspots identified through the workflow outputs, the analysis was further refined by examining the presence of socially significant gathering places, vulnerable facilities, and critical locations within these high-risk areas. The incorporation of this local information provided a more detailed understanding of who and what is exposed to the identified risks. In turn, this enables the municipality to prioritize adaptation measures more effectively and to design interventions that maximize benefits for the largest possible share of the population, while also ensuring targeted protection of vulnerable groups and critical infrastructure assets.

Pernik Municipality
Vulnerable Locations Inventory for Climate Risk Assessment

Category	Number of Locations
Healthcare facilities	4
Kindergartens	12
Primary and secondary schools	11
High schools and vocational schools	8
Day centres	3
Family-type accommodation centres	3
Crisis services	1
Cultural institutions	7
Open-air markets	4
Public squares	3
Elderly/disability services	8
TOTAL	**64**

Table 2-2 Summary of critical infrastructure analyzed in respect to the vulnerability component of the CRA framework.

In terms of climatic data, available data from NIMH was used to validate the results and seek any discrepancies that would speak to grave flaws in the workflow computations and such were not found. However, given this data was air temperature, the municipality has preferred to continue to work with the workflow Landasat8 data on surface temperature as most appropriate in terms of accuracy and prolonged measurement for the identification of heat islands.

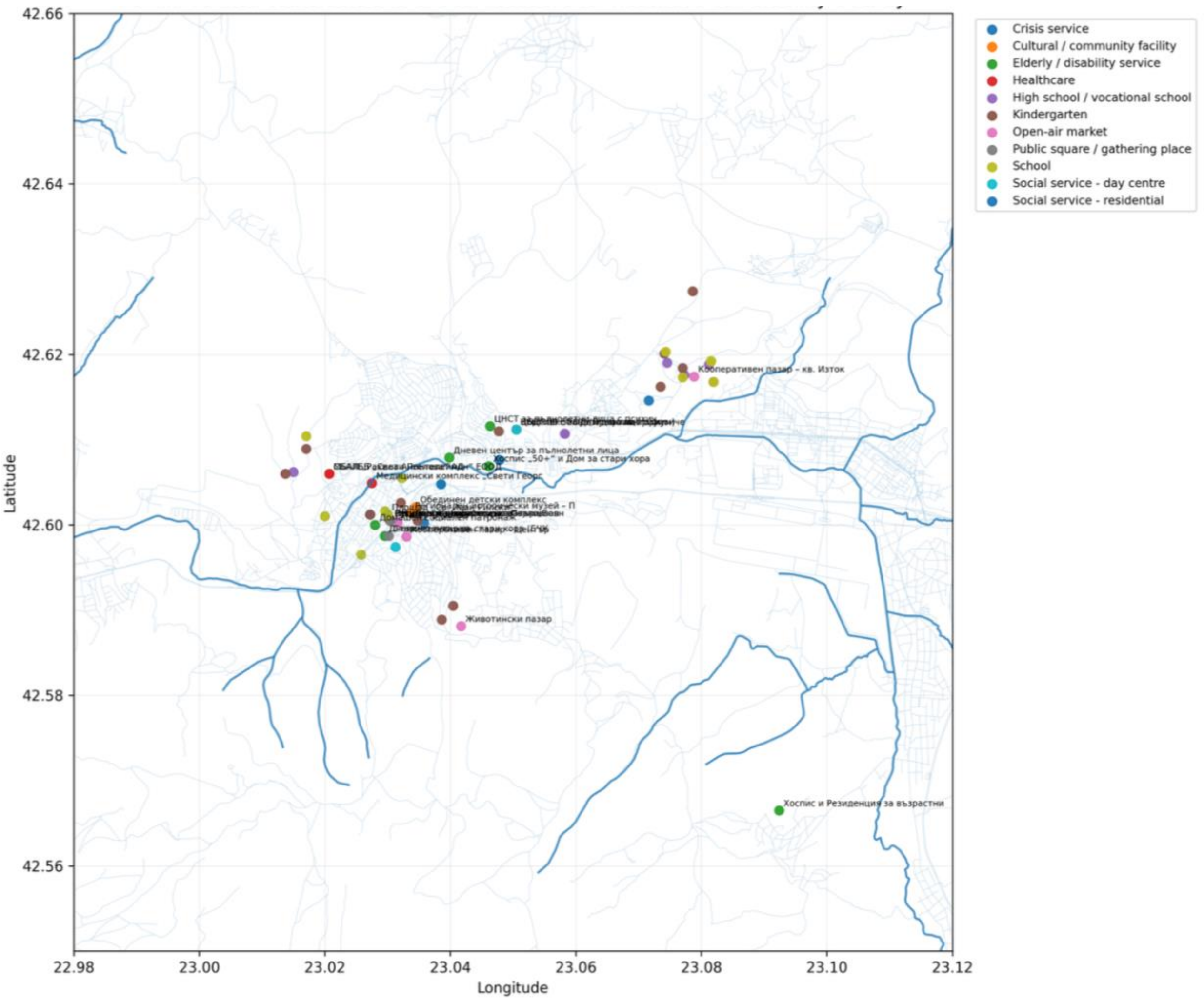

Figure 2-6 Heatwave risk to vulnerable population in the Municipality of Pernik with included social hubs and vulnerable infrastructure

Layering the local data on vulnerable locations with the workflow output about the heatwave hotspots, the municipality receives a list of locations to prioritize in adaptation measures, both targeted towards vulnerable groups and benefitting the majority of local residents by including locations of social importance and critical infrastructure. This has made a difference for the results as the concentration of vulnerable locations outlines concrete locations for prioritization where it overlaps with a high to medium level of possible heat risk level to vulnerable population

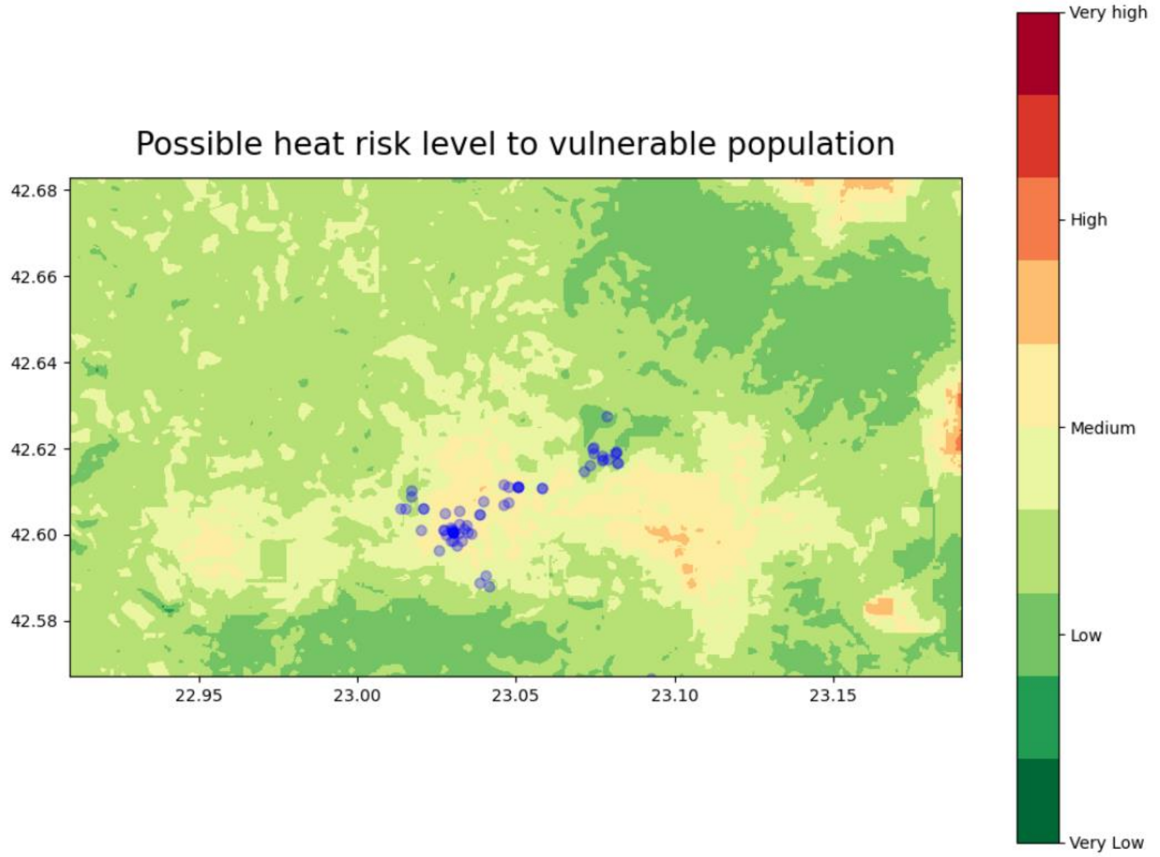

Figure 2-7 Possible heat risk level to vulnerable population with critical infrastructure layer for the municipality of Pernik

2.3.2 Hazard #2 - finetuning to local context: Heavy Rainfall / Extreme Precipitation

Table 2-3 Data overview workflow #2

Hazard data	*Vulnerability data*	*Exposure data*	*Impact metrics/Risk output*
CDS EURO-CORDEX climate projections for precipitation flux at a 12km spatial resolution: timeframes - 1976-2005	*Critical impact rainfall threshold incorporating data on what impacts are no longer sustainable or acceptable for local conditions*	*Critical impact rainfall threshold incorporating data on what impacts are no longer sustainable or acceptable for local conditions*	*Maps plotting shifts in magnitude and frequency of extreme precipitation events as defined by the threshold for two scenarios – historic and RCP8.5*

Hazard data	*Vulnerability data*	*Exposure data*	*Impact metrics/Risk output*
(baseline or historic simulations) and 2041-2070 (climate projections)			
NIMH analysis of the annual volume of precipitation	*Local data on vulnerable and critical infrastructure;*		*Granulated map of magnitude and frequency shifts identifying areas for prioritization.*

2.3.2.1 Hazard assessment

Phase 2 builds upon the computations done during Phase 1 and validates the results in terms of trends and outlook against local data and national projections. NIMH annual data reviewed consistently points towards the fact that while there are many parts of the country where less precipitation is foreseen and this is the predominant trend, in the case of Pernik municipality an increase is observed (NIMH annual bulletins, 2025-2020), for instance in the case of 2024 the overall annual volume of precipitation for the majority of the Pernik municipal territory showed a deviation from the norm by plus 80-200% (NIMH, 2025). These data, based on local NIMH measurements throughout the country, validate the outlook presented by the workflow for Pernik.

In Phase 1 the hazard workflow was applied to generate rainfall datasets corresponding to both current and future climate scenarios. The process involved several key steps, including the extraction of annual maximum precipitation values, the fitting of multiple statistical distributions, and the calculation of return periods for specific rainfall durations and climate scenarios. CDS EURO-CORDEX climate projections for precipitation flux at a 12km spatial resolution were used to assess future climate hazards. Historical simulations were derived from the timeframe from 1976-2005, while climate projections were based on the period from 2041-2070 for RCP8.5. The data was cropped for the studied region of Pernik municipality, and a combination of General Circulation Model (GCM), Regional Climate model (RCM), and a Representative Concentration Pathway (RCP) was used for plotting. The workflow plotted the temporal series of annual maximum precipitation for a selected location - in this case the city of Pernik and the entire region - in this case the municipality of Pernik. It was also used to plot the expected precipitation for a 3-hour event for a certain period for these two locations, as well as to compute precipitation changes in percentages for a particular year period. All these intermediary steps were then used to plot the results under the form of extreme precipitation maps that show the expected precipitation and the relative change for the period 2041-2070 under the RCP8.5, i.e. precipitation for 24 hours for a 10-year return period and the relative change compared to the baseline of 1976-2005 for a 10-year return period (See Figure 2-8). The plot results also compute mean values of expected precipitation versus return period for the historical and the future time-frames (See Figure 2-9). The workflow thus allowed to see how precipitation volumes are to shift under different climate change scenarios, in the case of Pernik municipality and the RCP8.5 in specific.

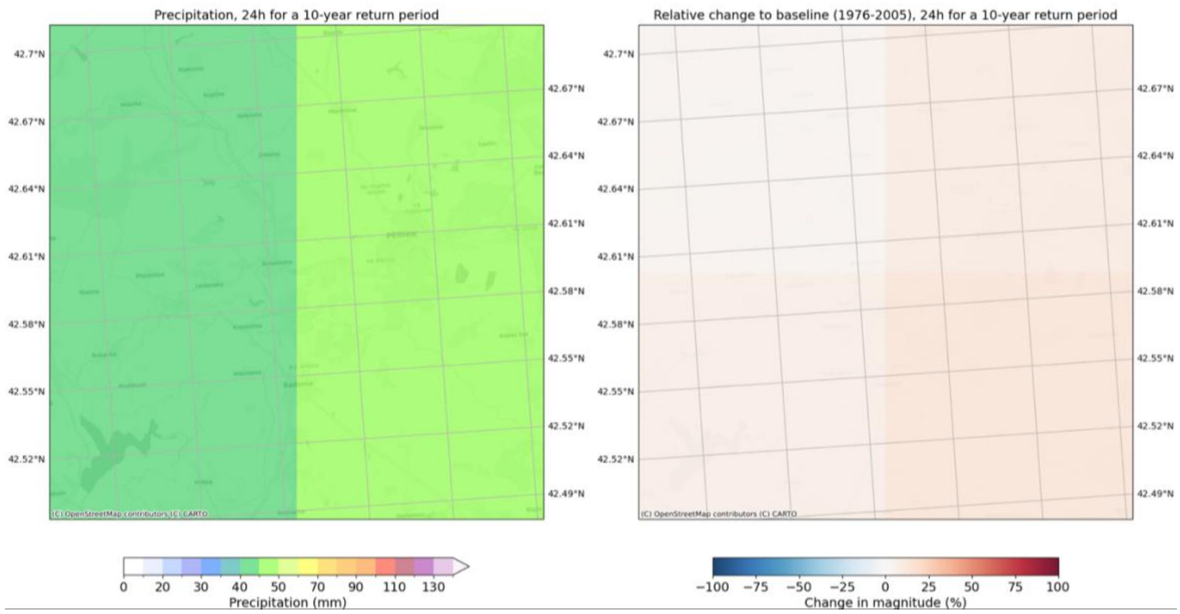

Figure 2-8 Extreme precipitation for 2041-2070 under RCP8.5 climate projections for the municipality of Pernik.

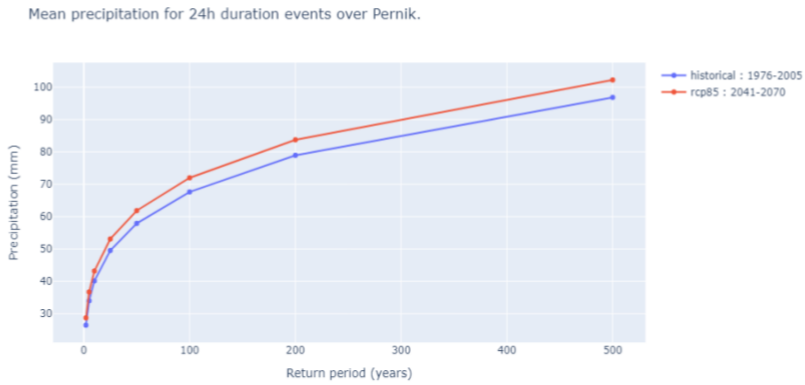

Figure 2-9 Mean precipitation for 24h duration events for historical and RCP8.5 scenarios for the municipality of Pernik.

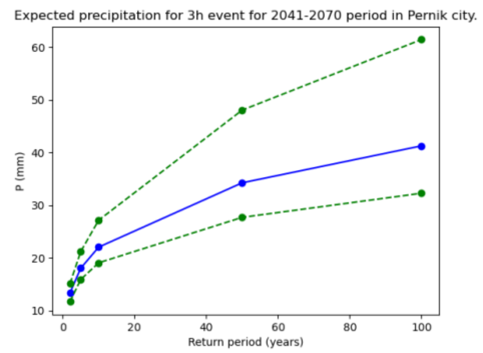

Figure 2-10 Expected precipitation for 3h event for 2041-2070 period for the city of Pernik.

2.3.2.2 Risk assessment

The extreme precipitation risk assessment methodology allows to analyze the risk associated with the extreme precipitation hazard by plotting how the current local critical impact-based rainfall thresholds will shift under climate change scenarios by taking into account two main elements – the magnitude and the frequency, i.e. a rainfall of what magnitude will occur with what frequency. The risk workflow has been applied to the specific location of the city of Pernik and the regional assessment of the municipality of Pernik (for clarity of terms please note that the word region is used liberally here to indicate a larger territory whereas in respect to administrative division, "region" under the Bulgarian national administrative division nomenclature is a unit above the municipal level and encompasses several municipalities). Hazard data has been used as generated by the hazard workflow and the CDS data has been plugged in its non-bias-corrected version. The historical timeframe refers to the period 1976-2005 and the future projections are based on the period 2041-2070. The projections are computed for the RCP 8.5 for the duration of 3 and 24 hours with the ichec-ec-earth/knmi_racmo22e as Global/Regional Climate Model Chain. Both the site specific and the regional assessment are carried out for the impact threshold of 35mm magnitude/24hr duration/3year frequency. The test of domain overlap between the historical dataset and threshold dataset verified the validity of the results. Due to lack of local data a dummy dataset was used for the code, where a tiff file with the local data had to be inserted, and the thresholds were fixed for all pixels at this one value. The generated plots for shifts in magnitude and frequency (See Figure 2-11 and Figure 2-12 respectively) are a valuable asset in planning adaptation and prevention measures.

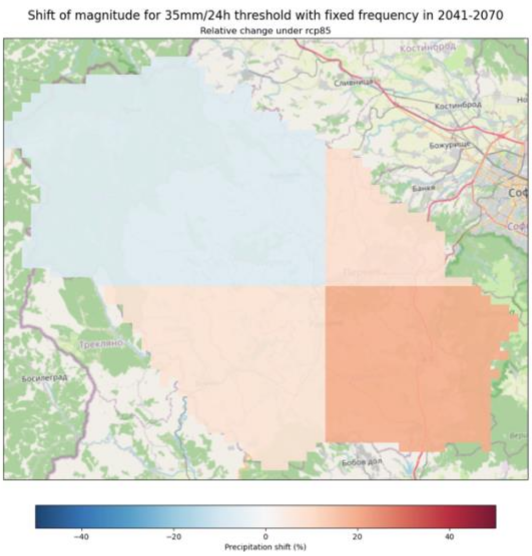

Figure 2-11 Shift in magnitude for 35 mm/24h threshold with fixed frequency in 2041-2070 under RCP8.5 for the Municipality of Pernik.

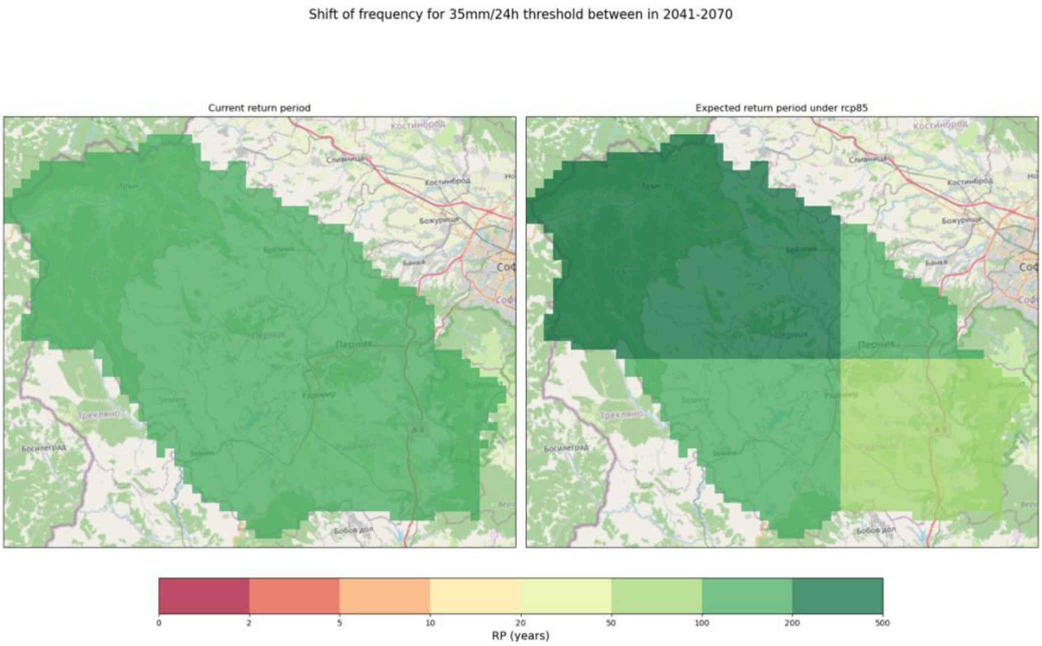

Figure 2-12 Shift in frequency for 35 mm/24h threshold between 2041-2070 for the Municipality of Pernik.

In Phase 2, the team has added a layer of local data on critical infrastructure for both outputs of the risk workflow as you can see in Figure 2-13. This layer shifts the analysis in practical terms as it points to two things. First, the critical infrastructure is likely to be affected differently not by the change in frequency as the points fall all under one category of shift but by a shift in magnitude.

Secondly, even the shift in magnitude would not produce such a dramatic differentiation in impact for those critical infrastructure points as they are again clustered closely together. So what will make the difference for those points where a shift is foreseen is the condition of local drainage infrastructure. Thus, from a policy perspective, the municipality should prioritize those points that are expected to have a shift in magnitude and where local infrastructure is not in good condition. During Phase 3 of the project, the municipality will create a list of these sites based on a review of the condition of local infrastructure in the identified locations.

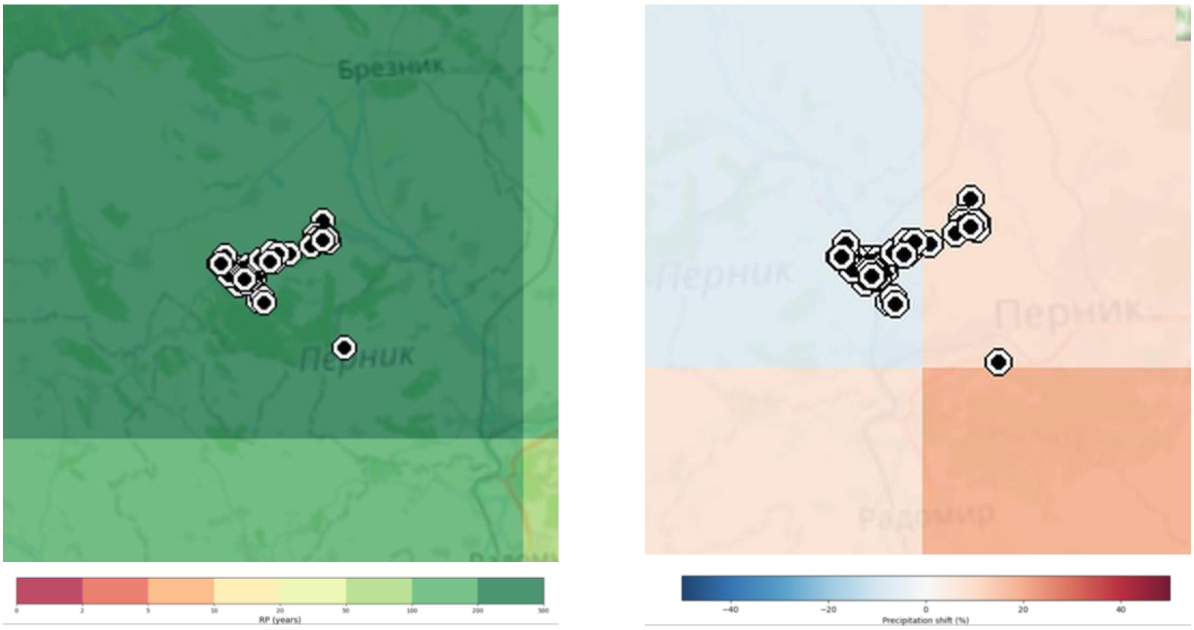

Figure 2-13 Overlay of critical infrastructure and vulnerable locations on the workflow outputs zoomed in on the urban area of Pernik town: shift in frequency on the left and shift in magnitude on the right. Color coding of workflow outputs is kept unchanged

2.4 Key Risk Assessment Findings

2.4.1 Mode of engagement for participation

The stakeholder engagement approach is described in Section 2.1.5. Feedback collected throughout the process was primarily centered around three key objectives of the communication activities: first, to validate or challenge the workflow outputs developed for Deliverable 1; second, to gather additional information and local insights that could support the refinement of the CRA in Deliverable 2; and third, to test how useful residents see the CRA results. Prior to the broader stakeholder consultations, the project team anticipated that the workflow outputs would largely be confirmed by stakeholders, and this expectation ultimately proved accurate. This assumption was based on a series of bilateral validation meetings and internal team discussions conducted before the submission of Deliverable 1. As a result, the team had relatively few concerns regarding the validity of the initial findings. At the same time, there was considerable interest in understanding whether stakeholders with different backgrounds, experiences, perceptions, and relationships to the identified risks would raise alternative perspectives or challenge the results. Such challenges, however, did not materialize. Instead, a broad consensus emerged among stakeholders that the workflow outputs were credible, reliable, and broadly consistent with conditions and experiences observed on the ground.

The most significant feedback received did not concern the validity of the findings themselves, but rather the need for greater specificity and contextual detail regarding their practical implications and usefulness. Stakeholders expressed a strong interest in understanding more precisely what the identified risk hotspots represented within the local context, including information related to infrastructure, adaptation interventions, population characteristics, and other relevant local factors. In essence, stakeholders called for a more detailed interpretation of the workflow outputs through the integration of local data (mostly non-climatic as they perceived the one included in the workflow as sufficient based on the results) enabling the CRA to become more operational, actionable, and easier to understand. This additional level of detail was considered necessary to provide clearer guidance on what is at stake, which locations and risk dimensions require priority attention, and where future adaptation efforts should be focused. Only with the addition of these local data stakeholders deemed that the CRA results will yield actual impact on policy and produce solutions.

2.4.2 Gather output from Risk Analysis step

Throughout the engagement process, the team considered it essential to clearly communicate how climatic hazards interact with the exposure and vulnerability components of the assessment, many of which are influenced by non-climatic factors. Particular effort was made to explain how these elements combine to shape overall risk and how this analytical framework underpins the CRA methodology. Stakeholders generally responded positively to this approach, noting that it helped make climate-related risks more tangible, understandable, and relevant to their everyday realities. Many participants indicated that the hazard-exposure-vulnerability framework reduced the perception of climate change as an abstract technical issue and instead presented it as a practical challenge with direct local implications.

The project team made extensive use of workflow outputs related to both the prioritized hazards and the associated risks. Regarding urban heatwaves, the team utilized the workflow outputs showing the projected increase in heatwave occurrence under both the RCP4.5 and RCP8.5 climate scenarios. Additional outputs incorporated into the analysis included maps identifying overheated areas as well as the interactive map illustrating heatwave risk for vulnerable population groups. For extreme precipitation, the analysis drew on the hazard outputs illustrating the increase in volumes of extreme precipitation under RCP8.5, while the risk dimension was communicated through the maps plotting the shifts in magnitude and frequency. It is to be noted here that the map on shift in magnitude was most useful and impressive with stakeholders .

2.4.3 Assess Severity

The Municipality of Pernik has evaluated the severity of the two priority climate risks - urban heatwaves and extreme precipitation based on the outputs generated through the CLIMAAX workflows by putting these to the test of stakeholder assessment and validation. Municipal administration representatives and experts were also considered part of the stakeholder group. It is important to highlight that in some respects, these were uniquely positioned to contribute valuable insights derived from their professional experience, institutional knowledge, and direct observations of local conditions – information that proved of crucial importance in assessing the risk severity.

The heatwave hazard assessment reveals a marked rise in the frequency of heatwave events under both future climate scenarios—RCP4.5 and RCP8.5. Notably, under the RCP8.5 scenario, the number of heatwaves is projected to double over the next two decades. Figure 2-1 illustrates this trend for the municipality of Pernik, showing a consistent increase in heatwave occurrence across both scenarios. This upward trajectory signals a pressing need for Pernik to adopt adaptive measures aimed at protecting its residents and economy from the escalating threats and cascading effects associated with heatwaves.

In complementarity, the heatwave risk assessment identifies priority areas within the municipality that require immediate attention. These include zones with both high heat exposure and dense populations - particularly in and around the settlements of Pernik, Batanovtsi, Bosnek, Kladnitsa, and Rudartsi. When considered alongside projections of rising heatwave frequency under both climate models, this spatial analysis provides a clear direction for targeted interventions aimed at reducing the overall impact of this growing hazard.

Heatwaves are known to trigger a chain of negative effects across various systems, including public health, energy infrastructure, water supply networks, and sectors like cultural tourism - a field that Pernik has been actively developing through festivals in recent years. Among these, the most immediate and critical risks are to human health, especially in densely populated urban areas. Vulnerable groups, such as the elderly and young children, face the highest risk. This challenge is particularly acute in Pernik, a municipality experiencing demographic aging, where many buildings lack modern insulation or air-conditioning systems, and where lower-income older and retired from the workforce residents are disproportionately affected by extreme heat.

The health-related consequences of heatwaves include increased mortality rates, heatstroke, dehydration, heat exhaustion, and the exacerbation of chronic or pre-existing medical conditions. Furthermore, issues related to access and quality of healthcare services compound these risks, highlighting the urgent need for targeted strategies to protect vulnerable segments of the population from prolonged heat exposure.

This analysis regarding the urban heatwaves risk was validated through stakeholder consultations, during which participants consistently emphasized the growing need for the Municipality of Pernik to implement adaptation measures aimed at reducing the impacts of heatwaves on both the local population and the economy. Stakeholders also highlighted that heatwave risk extends beyond direct temperature-related effects and generates a range of cascading consequences across multiple sectors and systems. Particular concern was expressed regarding the implications for public health, tourism, and water supply as increasingly vulnerable to the intensifying heatwave hazard. Still, stakeholders paid sufficient attention to the slow onset nature of the hazard, which gives the municipality a longer time horizon to act in prevention and adaptation and therefore despite the gravity of potential and current impacts, rated the risk as moderate in terms of severity.

Extreme precipitation severity is poised to increase as well for future projections. Under RCP8.5 for the future projection for 2041-2070 the entire territory of the municipality will be subject to precipitation for 24h (10 year return period) that exceeds the current threshold of 35mm. Spatially the Eastern part of the municipal territory seems at higher risk of extreme precipitation and settlements in this region should be prioritized in adaptation and disaster response measures and plans. The return period for 24h precipitation events of mean volume above 35mm is also projected to become shorter for the territory of the municipality under RCP8.5 and above 40mm the shift in intensity widens compared to the historical baseline data. In respect to the city of Pernik the volume for 3h precipitation events under the future projection is also seen to rise. The analysis clearly points to the need to organize adaptation measures around proofing infrastructure, educating the population, and preparing for response actions in urban areas with a relatively mid-term time horizon.

The plots from the risk workflow point to the areas where the shifts in magnitude and frequency will be most dramatic and therefore should be prioritized. The East and East-South territory of the municipality is again poised to have a rise in magnitude and a higher rate of a frequency shift compared to the baseline year and therefore should be considered with more attention and with priority. These identified areas prone to more severe impact from extreme precipitation also coincide with the path of the Struma river which indicated the potential for conflating risks, whereby extreme precipitation events could be conducive to river flooding. This is yet another argument to look at those areas with priority when planning adaptation and response measures.
In respect to the extreme precipitation risk, stakeholder feedback indicated broad agreement with these findings, with participants confirming that the results were consistent with their own observations, experiences, and expectations regarding the identified risk and its impacts. Stakeholders also confirmed the identified locations. At the same time, they emphasized the need for additional local detail regarding the condition of existing drainage infrastructure and possible cost-effective adaptation solutions for each location. According to stakeholder feedback, such information is essential for achieving a more accurate understanding of local risk conditions and for ensuring that future adaptation measures can be designed, prioritized, and targeted on the basis of a more comprehensive and precise assessment.

2.4.4 Assess Urgency

The assessment of urgency was informed to a significant extent by the perspectives of vulnerable groups and populations most exposed to the identified risks. Their experiences and concerns provided important insights into the immediacy of potential impacts and the need for timely action. In addition, expert judgment played a key role in determining urgency scores, particularly input from specialists with knowledge of institutional capacity, implementation timelines, and the practical requirements associated with planning and delivering adaptation measures for the two priority risks.

The consulted stakeholders agreed on the initial conclusions of the CRA described in the following paragraphs and highlighted that timely actions will be substantially supported by the CRA, especially in regard to making sure investments in adaptation measures are as cost-effective as possible given the limited availability of funds to this end.

Heatwave risk stems from a slow-onset hazard, which may not demand immediate crisis response but still calls for proactive and timely planning. Although the urgency might seem lower compared to sudden disasters, the current, tangible effects already justify the need for targeted adaptation measures. These actions can be initiated now and expanded incrementally over the next 10 to 20 years - particularly important under the more severe RCP8.5 scenario, where the frequency of heatwaves is expected to double.

Demographic trends, such as the aging population, act as non-climatic risk multipliers that could intensify the impacts if left unaddressed. This makes long-term planning even more crucial. Another key consideration is the scale and timeframe required for adaptation efforts. Many of these interventions - such as improving housing, greening urban areas, or upgrading public infrastructure - involve significant financial investment and extended implementation periods. Therefore, early initiation of planning and mitigation strategies is essential to ensure that the municipality is prepared to cope with increasing heat-related risks in the years to come.

Extreme precipitation arises from a sudden onset event, which is also harder to predict with climatic models and scenarios. Since the severity also is projected to increase, the municipality should take timely action to prevent floods by improving drainage infrastructure and to mitigate disturbances to the local population by organizing response plans and strategies for when extreme precipitation events occur. Under the RCP8.5 hazard plot for the future projection for 2041-2070 the entire territory of the municipality (Figure 2-8) will be subject to precipitation for 24h (10 year return period) that exceeds the current threshold of 35mm. Spatially, the Eastern part of the municipal territory seems at higher risk of extreme precipitation and settlements in this region should be prioritized in adaptation and disaster response measures and plans. The precipitation magnitude and frequency shift, however, indicates the municipality could prioritize adjusting to current impact levels first and then upgrade to higher impacts as the shift in magnitude seems to be below 20% for at least 2/3 of the municipal territory and can focus resources in preparation for more disruptive impacts in the 1/3 of the territory that is shown as prone to a higher percentage change in magnitude (Figure 2-11) and that coincides with the area of a shorter return period under RCP8.5 from the frequency shift risk workflow plot (Figure 2-12).

In terms of policy, the addition of the local data on vulnerable locations during Phase 2, has produced a major insight, namely – prioritization should be given to areas/sites where we see both shift of magnitude and clustering of vulnerable locations, combined poorer condition of local drainage infrastructure due to the clustered vulnerable locations that renders the shift in frequency much less important for variations amongst the locations (Figure 2-13).

2.4.5 Understand Resilience Capacity

Regarding urban heatwave risks, no formal management measures have been implemented at present and lack of understanding about the risk and its impacts has prevented the municipality from taking such actions or developing any relevant capabilities to act. The municipality issues warnings in advance of anticipated extreme heat, but no specific interventions have been introduced to mitigate associated impacts. The analysis conducted within the CRA framework has, therefore, provided valuable insights and a deeper understanding of this risk and the underlying hazard. These findings will guide the development of targeted adaptation strategies, facilitating more effective planning and improving the municipality’s capacity to plan for concrete measures and afterwards seek to obtain the necessary funding from both national and EU sources to implement those.

The Municipality of Pernik currently faces significant limitations in addressing the impacts of extreme precipitation events. Due to the rapid onset and often unexpected nature of these occurrences, preventive actions have been largely limited to the routine maintenance of relevant drainage infrastructure. In terms of disaster response, the municipality has established a disaster response and civil protection plan (Pernik Municipality, 2023). However, the scale of extreme precipitation events often requires the municipality to request regional support through coordination with regional authorities and the activation of the regional disaster response framework. Post-event recovery also presents considerable challenges, as restoration relies on support from national funding. The current state of risk management and disaster response capabilities underscores the urgent need for enhanced measures in prevention of floods from extreme precipitation, adaptation to other heavy rain impacts, and capacity building in risk governance. By incorporating this risk into the Climate Risk Assessment (CRA), the municipality is laying the groundwork to improve its prospects for securing national funding aimed at risk mitigation. Furthermore, this effort enhances its ability to pursue European Union funding and attract private investment to support risk management initiatives.

2.4.6 Decide on Risk Priority

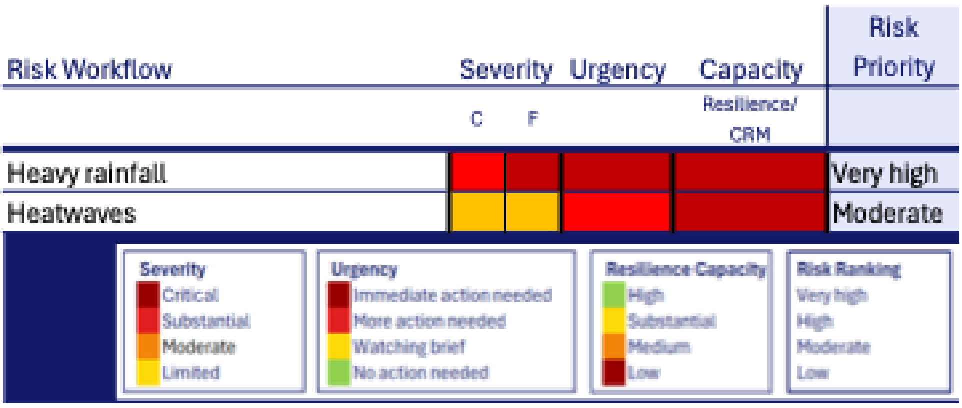

Figure 2-14 Risk prioritization of the two selected risks to analyze under the PERNIKCLIMAACT project

Risk prioritization was conducted through the application of the CLIMAAX Key Risk Assessment Protocol and the evaluation dashboard. The scoring of the different elements was determined through a series of internal team discussions drawing on the project team's knowledge, professional experience, and technical expertise, while also incorporating stakeholder input collected through both bilateral consultations and broader multi-stakeholder public engagement processes. This included feedback gathered during the public consultation organized within Phase 2 of the project, as well as relevant consultations held outside the PERNIKCLIMAACT framework that addressed one or both of the identified risks and where stakeholder observations had been formally documented.

As stakeholder feedback inevitably contains a degree of subjectivity shaped by personal experience, perception of risk, and proximity to hazard impacts, the project team exercised additional expert judgment particularly regarding the assessment of adaptive capacity. In this respect, the municipal administration was considered the most reliable source for evaluating institutional and operational capacity, given its direct responsibilities and knowledge of local governance conditions. Consequently, external stakeholder input played a more limited role in determining the final scoring for this specific component of the assessment.

2.5 Monitoring and Evaluation

The second phase of the project proved essential for exploring in depth the available data on the national level, as well as local knowledge, archival materials, and datasets connected to the two priority risks. It was central for gathering, organizing, and systematizing information that until now had remained fragmented across different sources. Nationally collected climatic and hydrological data from the National Institute of Meteorology and Hydrology (NIMH) is available but not readily accessible and limited and hence needs to be combined with local knowledge, experience, and observational data. Throughout the process of data selection and organization during Phase 2, it became increasingly evident that local information was highly valuable. Also, the team realized that non-climatic factors could significantly influence the manifestation and severity of climatic hazards, such as the condition of infrastructure or the surface material in highly urbanized areas. Consequently, additional data was incorporated into the CRA through targeted collection, extraction, and systematization of information from dispersed local sources, including interviews with municipal experts, alongside regional and national sources capable of capturing specific dimensions of the analyzed risks. European datasets used in the analysis already provided a sufficiently reliable climatic basis, while the greatest need for local detail related primarily to non-climatic drivers necessary for improving the precision and practical relevance of the assessment. As a direct outcome of Phase 2, the municipality intends to explore future possibilities for establishing local systems for recording climatic data but also for collecting and organizing the storage and use of non-climatic data and looking into the possibility to involve citizens as much as possible in its collection and prioritization in line with the idea about citizen science.

One of the most significant challenges encountered during Phase 2 was to select the relevant local data that will allow the team to get the most out of the workflows and their output analysis. At first, we focused on the climatic data that we could potentially add/substitute but then after reviewing what was available we came to the realization that it was important for validation and to check the outputs against it to see if there are disproportions in the outputs that point to a computational flaw in respect to climatic realities. What we actually needed to refine the workflow outputs and operationalize them was not so much additional climatic local data but data that clarified the vulnerability and exposure aspects of the analytical framework. Once we realized this, we focused to finding out what will bring most value for policies and practical decisions locally and hence added the local non-climatic data.

During Phase 2, the project team also learned that the challenge of limited stakeholder understanding of climate change-related issues can be substantially mitigated when discussions focus on concrete results and their validation through stakeholder observations and lived experience, while also linking these findings to potential policy measures and adaptation options. In practice, stakeholder consultations largely confirmed the outputs generated through the workflows and highlighted the need for additional local detail, particularly concerning non-climatic factors. This feedback motivated the team to further refine the workflow outputs through the incorporation of local data in order to increase the level of detail in identifying risk hotspots for both analyzed hazards. Participants emphasized that the aspects of exposure and vulnerability helped them better recognize how the insights produced through the CRA could be translated into concrete policy decisions, strategic planning documents, and future adaptation action plans. According to the feedback, the framework of the CRA has strengthened the perception that local stakeholders are actively contributing to solutions for climate-related challenges, while also increasing public understanding of current and future policy processes.

Continuous learning within the municipal team has been actively supported through regular internal discussion sessions focused on reviewing progress, discussing encountered challenges, possible solutions, and opportunities for improving future administrative practices. These exchanges have helped identify ways to reduce similar difficulties in the future. For example, during Phase 2 the team developed ideas for creating structured municipal databases capable of continuously collecting and storing information relevant to climate risks. One proposed initiative involved establishing a centralized database covering all social hubs in the city and their surface material, alternatively – database with the status of the water drainage system and up-to-date maintenance information. At present, such information is not consolidated in a single location, and organized to serve adaptation efforts with most ease and effectiveness.

From the perspective of internal institutional learning, the team considers that available resources were utilized effectively. The municipal administration played a central role in data collection and validation while maintaining close coordination with the contracted expert team responsible for supporting the completion of the refined CRA. This determination the municipality to refine the CRA sufficiently to increase its usefulness for policymaking and stakeholder engagement purposes. Although the process was challenging, the process of obtaining the required information deepened the understanding about the analytical framework underlying the assessment, namely the relationship between hazard, vulnerability, and exposure. The CLIMAAX methodological framework has provided the guidance and confidence that the analytical process was moving in the correct direction. The determination, coordination, and efficiency of both the municipal administration and the subcontracted expert team were also critical for the successful completion of the refined CRA.

The process of collecting data related to the two priority risks analyzed within the CRA was itself characterized by continuous reflection and adaptation. The team regularly reassessed what information was necessary and adjusted the approach depending on whether the required data could realistically be obtained. As a result, the data collection process became an important learning experience in its own right. At this stage, the municipality believes it is now sufficiently prepared to establish a more systematic monitoring framework capable of continuously gathering information related to key risk-relevant factors in the future.

The municipality plans to communicate the final CRA results through a public consultation event in Phase 3. The purpose of this consultation will be not only to present the final assessment results, but particularly to demonstrate how stakeholder feedback and locally collected data contributed to refining the initial workflow findings and conclusions. In relation to regional and national stakeholders, the municipality intends to communicate the final outcomes through official correspondence summarizing the key findings and explaining how the knowledge and experience gained through the project can contribute to climate risk analysis, strategic planning, and policymaking at broader governance levels.

The overall impact of the CRA has been extremely valuable for the municipality, not only because of the final analytical outputs, but also because of the participatory process through which the assessment was developed. The CRA process enabled the municipality to engage local stakeholders and the broader public in a more accessible and relatable manner, facilitating concrete contributions and demonstrating clearly how stakeholder feedback can influence both the analytical process and the resulting conclusions. In this way, the project has contributed significantly to strengthening stakeholder participation, and confidence in climate change consultation processes. At the institutional level, the CRA has also improved understanding of climate risks, consolidated existing administrative capacities, and helped identify areas where future capacities should be further developed or streamlined. It provides a strategic foundation that allows the municipality to use its limited institutional resources more efficiently by ensuring that future decisions are guided by the findings of the CRA and implemented through a coherent long-term approach. In addition, the CRA process itself has served as an important capacity- and skills-building exercise for the municipal administration. Finally, and perhaps most importantly in terms of long-term impact, the refined CRA is expected to play a decisive role in helping the municipality secure national funding, access EU financial instruments, and attract investment for adaptation initiatives and measures. The document will provide a strong analytical foundation supporting future funding requests, advocacy efforts, and engagement with potential investors.

2.6 Work plan Phase 3

Phase 3 is key to the project as it is the stage that incorporates the produced refined CRA into municipal policy and adaptation measures. Therefore, the focus in this final phase will be to study how the obtained results – i.e. the refined CRA – can be translated into policy decisions by upgrading the municipal climate adaptation strategy and designing an action plan for its implementation. Another focus would be to study how it can improve regional and national planning and strategic approach to climate adaptation and disaster readiness in respect to the two risks. Last but certainly not least in importance will be the quest to improve local ownership of the policy decisions by affected groups to ensure public support that will translate into sustainability of the efforts.

This third phase comprises of the following two activities:

Activity 3.1: reviewing the municipal climate adaptation strategy in light of the results from the study and upgrading it by proposing concrete changes to the text of the document and supplementing it with an action plan for its implementation.

Activity 3.2: sharing the study results with the relevant regional and national authorities to contribute to the regional efforts for disaster prevention and early warning and organizing a meeting with local residents and the business to share the refined results and to explain what they mean for practical measures.

3 Conclusions Phase 2- Climate risk assessment

During Phase 2, following the analytical logic of assessing risks through the interaction between hazard, vulnerability, and exposure, the initial CRA underwent a substantial refinement process through the integration of local and national data into the workflow outputs. This refinement resulted in the current finalized CRA through the incorporation of local information used to further granulate and most importantly operationalize the workflow results, i.e. making the CRA more practical, accessible, and policy-oriented document for decision-makers and non-expert audiences. The fact that the refinement process was informed by stakeholder feedback on the initial CRA has greatly contributed to improving its palpability and usability. Phase 2 has transformed the CRA into a sufficiently operational and actionable document to effectively support local policy development and decision-making.

During the second phase, the main focus of project activities was directed toward integrating additional layers of local information in order to strengthen the robustness of the analysis and make the results easier to interpret and apply in practice. Most of the difficulties encountered were linked to the identification, selection, verification, extraction, collection, and systematization of local data and knowledge. As anticipated, locally available climatic information was limited. Important to note, however, is that when available it confirmed workflow output conclusions. Due to the limited availability of this data, however, the team has tried to strengthen the CRA refinement by incorporating local information particularly into the exposure and vulnerability components of the assessment. The municipality is convinced that combining the workflow outputs generated through European-level climatic datasets with local information on vulnerability and exposure considerably improved both the clarity and practical value of the CRA outputs, making the findings more understandable and directly usable for policymakers, implementing institutions, and other relevant stakeholders. Phase 2 has substantially highlighted the major role that non-climatic factors, drivers, and local systems can play in operationalizing workflow outputs and interpreting climate-related risks.

Following the establishment of the necessary technical infrastructure, software environment, and working processes for implementing the CLIMAAX framework during Phase 1, significantly fewer technical difficulties were encountered in Phase 2. The CLIMAAX Community of Practice webinars also continued to provide substantial value, especially as the thematic focus of these online sessions increasingly shifted toward policy formulation, implementation mechanisms, and funding opportunities. The municipality greatly appreciated this orientation, and through exposure to various examples and experiences, the team feels that participation in the broader CLIMAAX network has strengthened its confidence and determination to move forward with concrete actions addressing climate-related risks on the basis of the CRA findings.

The Second Phase emphasized the importance of stakeholder engagement, particularly in relation to the contribution of local non-expert knowledge, which proved to have multiple forms of added value. Most importantly, stakeholder input played a crucial role in validating the CRA findings and grounding the analysis in practical local experience and expectations. At the same time, the team found it challenging to communicate certain technical aspects of the workflow analysis process to non-expert audiences. Consequently, greater emphasis was placed on explaining the results themselves and their practical implications. Through this engagement process, it became clear that stakeholder feedback also directly guided the refinement of the CRA by emphasizing the need for additional local detail capable of clarifying specific outputs. For example, stakeholders stressed the importance of understanding what specific extreme precipitation flood-risk hotspots contain in terms of drainage capacity, surface water absorption, population concentration, and similar contextual elements. Such information was considered necessary in order to prioritize adaptation measures effectively and ensure that the CRA results could support concrete operational decisions by the municipality.

At a broader analytical level, the key findings emerging from Phase 2 developed in three main directions. The first sought to validate or challenge the workflow outputs through comparison with local stakeholder knowledge and locally available data, ensuring that the findings from Phase 1 accurately reflected conditions on the ground as experienced by those directly exposed to or responsible for addressing the identified risks. The second direction focused on integrating additional local data to improve the precision and detail of the assessment outputs. Overall, the workflow results were overwhelmingly confirmed by stakeholders, while the European climate-related datasets used in the workflows were not questioned as inappropriate or unrepresentative for the region. The third direction was centered around operationalizing the findings by adding more non-climatic practical local information to the outputs, mainly through the hazard and vulnerability components of workflows.

In terms of key workflow findings, Phase 2 has served well for building upon the results and analysis from Phase 1 and arriving at new insights that have contributed to operationalizing the CRA. For the heatwave workflow, the key findings of Phase 2 were primarily related to refining the analysis through the incorporation of local data on vulnerable locations, which were identified in two directions – locations of social concentration in general or services for either of the vulnerable groups. This additional detail enabled a more precise prioritization of adaptation efforts based on the proportional impact that future measures could have on population health and comfort, as well as on the sustainability and functioning of sites and venues that are important for the social/health/cultural and other aspects of community life within the municipality. The key findings related to the extreme precipitation hazards and risks in Phase 2 contributed substantially to identifying and prioritizing locations for the phased implementation of adaptation measures. This was achieved through the inclusion of additional information concerning the concentration of socially significant sites and infrastructure as vulnerability-related factors. Particular attention was paid to facilities serving vulnerable groups that would be difficult to evacuate during flood events due to extreme precipitation.

At the political and strategic level, the findings generated during Phase 2 — and especially the increased level of operational precision achieved through the refinement process — have strengthened the municipality's commitment to advancing climate adaptation planning and implementation activities as soon as possible. Following the completion of the PERNIKCLIMAACT project, the municipality therefore intends to continue closely monitoring developments at EU level related to implementation support mechanisms, while also actively advocating for similar support structures and opportunities at both regional and national level.

4 Progress evaluation

This second deliverable, which builds upon the initial CRA through the integration of additional local data, will provide Pernik Municipality with the main analytical foundation for all activities planned under Phase 3. The findings and conclusions of the refined assessment will be directly integrated into local policymaking processes, particularly through the revision and upgrading of the municipal Climate Change Adaptation Strategy and an implementing Action Plan.

Deliverable 2 will additionally form the basis for future dissemination and stakeholder engagement activities. These efforts will aim both to continue gathering stakeholder input during the policy development stage and to strengthen local ownership of climate-related policies and of the broader climate change agenda within the community.

The refined CRA will further support engagement with regional and national stakeholders by serving as an evidence base for improving regional efforts for disaster prevention and early warning but also for advocating for targeted funding for concrete adaptation measures. In parallel, it will promote an understaning about the benefits of a broader application of the CRA-based approach in strengthening climate adaptation planning, coordination, and decision-making at regional level.

Table 4-1 Overview key performance indicators

Key performance indicators	*Progress*
Successfully apply 2 workflows (“Heatwaves” and “Heavy Rainfall”) for Deliverable 1;	Completed during Phase 1.
Hold 1 consultation meeting with local and regional stakeholders to: (1) present the PERNIKCLIMAACT project and the initial climate risk assessment (CRA) results (from Deliverable 1), (2) announce communication channels for stakeholders to share available data, input, and experiences that would support the refinement of the CRA, as well as (3) to collect any feedback and input on climate risks that the stakeholders can readily share at the meeting (meeting to be held after Deliverable 1 is completed so as to feed into the data for Deliverable 2);	Completed in Phase 2.
Take 3 communication actions to share results/progress with stakeholders (e.g. media publications, social media posts, in-person and online events, dissemination and delivery of presentations), whereby the following aims will be achieved respectively: o announcement of the results from Deliverable 1 and raising awareness on how the CRA will benefit local residents by improving municipal and regional climate change adaptation policy and efforts;	Partially completed in Phase 2, to be completed fully in Phases 3.

Key performance indicators	*Progress*
○ announcement of results from Deliverable 2 and raising awareness on how the refined CRA will benefit local residents by improving municipal and regional climate change adaptation policy and efforts; ○ announcement of results from Deliverable 3 and raising awareness on how the refined CRA has been used to improve the municipal climate change adaptation strategy.	
Successfully apply 2 workflows for Deliverable 2 (Phase 2);	Completed in Phase 2.
Hold 1 discussion meeting with local and regional stakeholders on the PERNIKCLIMAACT refined climate risk assessment and its impact on the municipal adaptation strategy (Phase 3);	To be completed in Phase 3.
Update the Climate change adaptation strategy for the municipality of Pernik based on the CRA and supplement it with an action plan (Phase 3);	To be completed in Phase 3.
Carry out 1 outreach initiative to regional authorities to promote prevention based on the produced CRA and contribute to improved regional coordination (Phase 3);	To be completed in Phase 3.
Carry out 1 outreach initiative to national level policy-makers to promote prevention based on the produced CRA and to advocate for funds for the municipality to implement adaptation measures based on the CRA and its Climate Adaptation Strategy (Phase 3).	To be completed in Phase 3.

Table 4-2 Overview milestones

Milestones	*Progress*
M1: Test of workflow 1 conducted (Phase 1);	Completed during Phase 1.
M2: Workflow 1 successfully applied (Phase 1);	Completed during Phase 1.
M3: Test of workflow 2 conducted (Phase 1);	Completed during Phase 1.
M4: Workflow 2 successfully applied (Phase 1);	Completed during Phase 1.
M5: Climate Multi-Risk Assessment (Deliverable 1) completed and submitted (Phase 1);	Completed and Deliverable 1 submitted during Phase 1.

Milestones	*Progress*
M6: Attend the CLIMAAX workshop in Barcelona (Phase 1 tentatively as indicated by the CLIMAAX coordinator);	Completed during Phase 1.
M7: Consultation meeting with local and regional stakeholders to discuss the CRA under Deliverable 1 and announce a channel for collecting input on climate risks completed (Phase 2);	Completed in Phase 2.
M8: A database of available and relevant to the workflows regional and local data created (Phase 2);	Completed in Phase 2.
M9: Refined multi-risk assessment (Deliverable 2) completed and submitted (Phase 2);	Completed in Phase 2.
M10: Climate Change Adaptation Strategy of the Municipality of Pernik reviewed and upgraded based on the refined climate multi-risk assessment (Deliverable 3) and supplemented with an action plan for its implementation (Phase 3).	To be completed in Phase 3.
M11: A discussion meeting on the refined multi-risk assessment with local and regional stakeholders and its impact on the municipal climate change adaptation strategy held (Phase 3).	To be completed in Phase 3.
M12: An out-reach effort to national authorities to advocate for funding for climate adaptation measures in the municipality on the basis of the multi-risk assessment initiated (Phase 3).	To be completed in Phase 3.
M13: An out-reach effort to regional authorities advocating for an improved regional approach to planning and prevention in respect to climate change impact and disasters, based on the multi-risk assessment initiated (Phase 3).	To be completed in Phase 3.
M14: Attend the CLIMAAX workshop held in Brussels (Phase 3 tentatively as indicated by the CLIMAAX coordinator).	To be completed in Phase 3.
M15: Subcontracting support completed (Phase 3).	To be completed in Phase 3.

5 Supporting documentation

- Deliverable 2 CRA Report in PDF - current document, submitted on the CLIMAAX Deliverable Platform.
- Zip file with local data on Workflow 1 and rerun of the risk workflow: Urban heatwaves (submitted in Zenodo, DOI: 10.5281/zenodo.21027288)
- Zip file with local data for Workflow 2 and rerun of the risk workflow: Extreme precipitation (submitted in Zenodo, DOI: 10.5281/zenodo.21027288)
- Zip file with plots, results, and workflow notebooks for hazard and risk for Workflow 1: Urban Heatwaves - Zenodo DOI: 10.5281/zenodo.17232462
- Zip file with plots, results, and workflow notebooks for hazard and risk for Workflow 2: Extreme Precipitation - Zenodo DOI: 10.5281/zenodo.17232462

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