Climate Risk Assessments at the Municipal Level

Recommendations for the Implementation of ISO 14091

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Introduction

1 Introduction

In view of the ever-increasing progress of climate change, the importance of climate risk assessments is growing. They play a major role at the municipal level in particular (cities, districts, municipalities), because it is here that precautionary action must take place in the face of the dangers of the climate crisis.[1]

Every municipality is affected by climate change, but in different ways – a result of spatial conditions and socio-economic factors. Climate risk assessments enable municipalities to identify and prioritise the impacts of climate change that are relevant to them, such as drought, heavy rain or heat. Municipalities can, for example, determine what or who is most affected, i.e. whether heat stress for people or flooding of buildings poses a climate risk, and the location of the most vulnerable areas.

The added value of municipal climate risk assessments lies in the fact that

- They represent a locally specific foundation for municipalities to determine appropriate climate action and become more resilient to the effects of climate change.
- They provide a solid basis for decision-making so that municipalities can prepare the adaptation process in a targeted and planned manner. This long-term perspective is important because many measures to adapt to climate change take a long time to take effect and involve significant investment.
- Cross-sectional assessments help identify the municipal departments that should work together on planning and adaptation. An interdisciplinary approach is important due to the cross-cutting nature of climate adaptation, both to take advantage of synergies and discuss potential conflicts. This makes it easier to work out solutions.

The recommendations in this paper provide support for the preparation and implementation of climate risk assessments at the municipal level. They summarise the international standard *"Adaptation to climate change – Guidelines on vulnerability, impacts and risk assessment"* (ISO 14091:2021-07)[2] and supplement this general guideline with specific recommendations for municipalities. However, this does not replace the consultation of ISO 14091 when planning a climate risk assessment at the municipal level.

The recommendations are aimed at actors responsible for the climate adaptation process at the municipal level. Who takes on the control and coordination of the process depends on where the topic is located within the respective local government. The target group is primarily experts who already have prior knowledge of climate change (e.g. climate adaptation managers) or who have enough time to familiarise themselves with the subject. External service providers who have been commissioned with a climate risk assessment can also make use of the recommendations for action.

This paper addresses municipalities that can use the recommendations for their own climate risk assessments, as well as municipalities that want to commission an external service provider; the latter can use these recommendations as a guide when formulating the call for tenders. The recommendations are primarily aimed at those who have sufficient capacity to carry out a climate risk assessment. Individual text boxes with hints and helpful information have been added for small and financially weak municipalities. The addressees of the recommendations also include groups of several small and medium-sized municipalities that work together to adapt to climate change. Accordingly, when the following paper mentions "municipalities", this includes municipal associations. In principle, it is advisable to conduct an inter-communal,

1 In March 2022, the Federal Ministry for the Environment presented the "Immediate Climate Adaptation Programme" to support municipalities in Germany in taking appropriate action: https://www.bmuv.de/download/sofortprogramm-klimaanpassung

2 https://www.beuth.de/de/norm/din-en-iso-14091/331247900

cross-district or regional climate risk assessment in order to identify cross-community climate risks in a resource-efficient manner and develop joint solutions.

The climate crisis affects both natural systems (forests, soil, seas, bodies of water, ecosystems) and systems dependent on natural resources (agriculture, forestry, fisheries, water management, industry, commerce) – i.e. all areas of human life and health. Since there are close causal relationships between climate risks in these different areas, the reduction of climate risks and adaptation to the unavoidable consequences of climate change is an interdisciplinary task. This starts with the assessment of climate risks, which requires both broad technical knowledge and the cooperation of different areas of expertise.

In this way, climate risk assessments are both complex and subject to high levels of uncertainty. Many aspects are interrelated and the climate crisis is changing familiar probabilities. The results of a climate risk assessment can lead to a shift in priorities and the initiation of uncomfortable change. In order not to be overwhelmed by the complexity and possible conflicts, those involved should approach the assessment pragmatically and constructively. In view of the magnitude of the task, sectoral and personal interests should take a back seat to the common interest of creating climate-resilient municipalities, i.e. communities that are resilient to climate change, in which future generations can also live happily and well.

These recommendations contain a compilation of tips and information on how to carry out municipal climate risk assessments (Chapter 2). The recommendations are based on the findings of the Climate Impact and Risk Assessment 2021 for Germany (Kahlenborn et al. 2021b), practical experiences of the authors involved, the Guidelines for Climate Impact and Vulnerability Assessments (Buth et al. 2017) and the results of a targeted exchange with a large number of municipal representatives. The recommendations are based on the structure of ISO 14091.[3] Since the recommendations refer directly to the ISO standard, each sub-chapter from Chapter 2 is preceded by a brief summary of the corresponding section of ISO 14091 *(see paragraphs in italics)*.

Legend
Info boxes contain further explanations and information in addition to the recommendations. Help boxes are aimed specifically at small and financially weak municipalities.

Info box

Help box

3 For reasons of manageability, some of the outline points have been combined.

Climate Risk Assessment (CRA)

The aim of a CRA is to identify and evaluate location-dependent and overarching climate risks, to assess the adaptive capacity if necessary, to determine the needs for action and to prioritise them according to their urgency. The results of a CRA can help develop climate adaptation action and combine those measures into an overall concept. In this way, a CRA forms the basis for climate adaptation concepts.

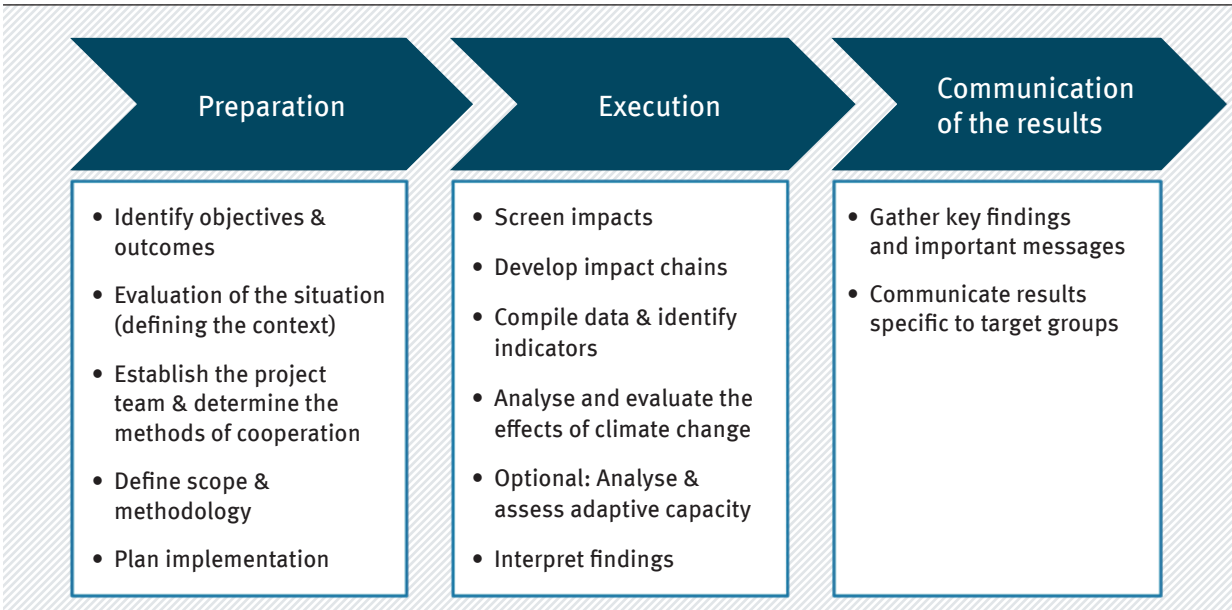
CRAs use model-based projections of climatic drivers and socio-economic factors to estimate the future impact of climate change on vulnerable systems and regions. In contrast to urban climate assessments or heavy rain maps, all relevant climate effects and their interdependencies are taken into account – depending on the definition of the area of application. This enables a cross-thematic, integrated consideration of the risks. How small-scale areas of risk within a municipality can be identified using a CRA depends on the specified area of application, the availability of data and its spatial resolution.

ISO 14091 identifies three phases of a CRA (see Figure 1):

- Preparation
- Execution
- Communication of the results

Figure 1

Overview of the recommendations for the implementation of a CRA



Source: adelphi, based on ISO 14091:2021-07

2

Recommendations

2 Recommendations

2.1 Preparation of a climate risk assessment[4]

The preparatory phase forms the basis for a successful CRA and aims to define the framework, goal and expected results of the assessment. At the same time, the project team is put together, the methodology is determined and an implementation plan is drawn up (see Figure 2).

2.1.1 Identifying objectives and expected outcomes[5]

According to ISO 14091, the objectives and the key questions for the CRA should be formulated as part of the preparation (e.g. "How will climate change affect my community in the future?", "In which areas is urgent action required?").

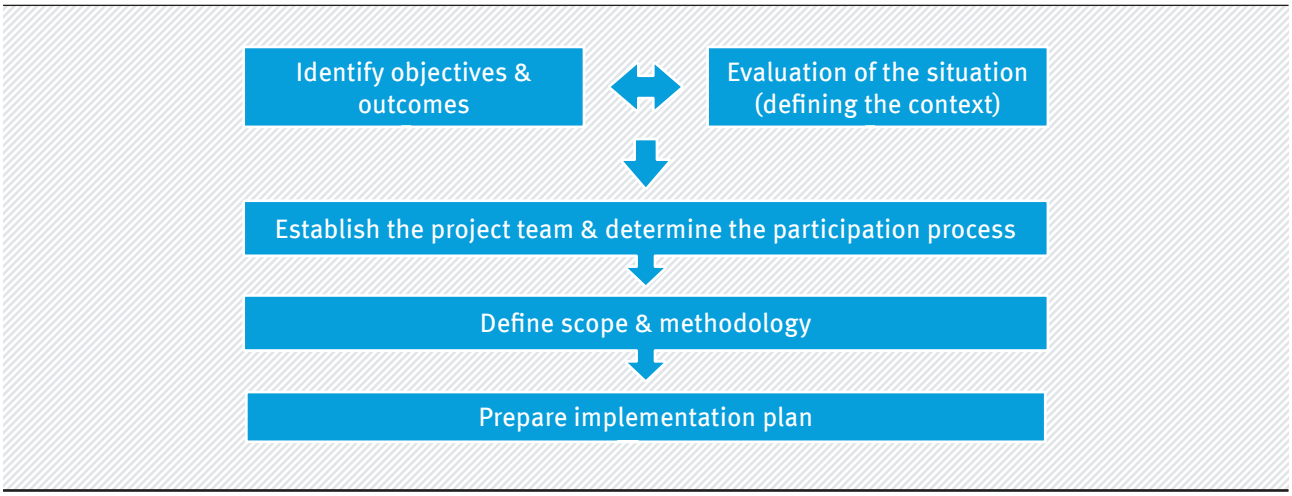
- The commissioner of a CRA should define what kind of outcomes are to be achieved and what they are to be used for. Accordingly, key questions can be defined that would have to be answered as part of the assessment. On the basis of these questions, the methodology can be selected later.
- When defining the goals of a municipal CRA, the city/municipality level and the district level should be distinguished. In most cases, it makes sense to involve both levels.
- The results of a CRA, e.g. the identified risks, are mostly needed at the municipal level in order to gain clarity about risks and prioritise them. This in turn justifies the need for action and enables the development of tailor-made adaptation measures.
- Since climate change is a continuous process and the scientific engagement with it constantly brings new findings to light, it can make sense to update a CRA after a certain period of time. This aspect should be taken into account when defining goals.
- A political decision on the defined goals of the CRA increases their binding nature.

4 Chapter 5 of ISO 14091

5 ISO 14091 starts with defining the context. The second step is to determine the goals. In these recommendations, the two sections have been swapped. In practice, setting goals and establishing context run in parallel and are iterative processes. The goals can only be finalised when the situation is already somewhat familiar, and the context can only be finalised when the goals have been largely defined.

Figure 2

Essential steps to prepare for a CRA



Source: adelphi

2.1.2 Evaluation of the situation[6]

Research locally relevant information

The situation of the municipality, i.e. the socio-economic and geographical conditions as well as typical trends (e.g. demographic change, urbanisation tendencies) should be taken into account in the preparatory phase (establishing the context).

In addition, an initial overview of existing local information on past and future climate risks is required.

- Natural systems are the essential basis for all areas of social life, the economy and human health and, at the same time, are particularly threatened by climate change (Kahlenborn et al. 2021b). This should also be one of the central starting points for the assessment of climate risks, causal relationships between action fields and the assessment of adaptation priorities at the municipal level.

- In order to establish the context for a municipality, the structures that are particularly sensitive to climate change, such as nature reserves, hospitals, critical infrastructure or supply chains should be identified along with vulnerable groups of people.

- In the preparatory phase, information on past local extreme climatic events, such as floods, drought or heat waves, and the associated damage, should be compiled in order to identify action fields that have been affected so far. Information on the consequences of gradual changes, such as the gradual rise in temperature or sea level rise, should also be collected.

- As a result, it should be possible to more or less identify all action fields and systems affected by climate change.

Identify interested parties and plan participatory approaches

ISO 14091 recommends the use of participatory approaches in a CRA. This should involve interested parties with relevant expertise in the decision-making process at an early stage. Participation promotes the common understanding and sense of responsibility of all participants and at the same time serves to raise awareness.

- The municipal departments and local actors in the action fields potentially affected by climate change should be named and addressed (e.g. department for the environment, urban development and urban planning, real estate, civil engineering, transport, tourism, agriculture, winegrowers, foresters, health, social affairs). The responsibility and coordination of this can lie, for example, with the climate adaptation manager of a municipality, the climate coordination office or with a municipal representative with a similar area of activity.

- In order to address all technically relevant and responsible official actors, the distribution of administrative responsibility in the various departments on several levels must also be taken into account (city/municipality, district, federal state), as well as shared or separate responsibilities.

- It is also relevant to make clear to administrative staff that they share responsibility for dealing with the consequences of climate change. Information events can serve to promote participation in the CRA.

- The interdisciplinary composition of the extended group of participants is important for prioritising climate risks and deriving the need for action in a later step of the CRA (see Chapter 2.2.4 ff.). Early participation and acceptance of the results is also important, as concrete tasks for municipal actors can be derived from this when planning action.

6 In ISO 14091, this section of the CRA is referred to as “Establishing the context”.

- In order to underline the importance of the CRA as a basis for the creation of a municipal climate adaptation concept, it is advisable to sensitise local political actors and elected officials to the process and, if necessary, involve them (e.g. as specialists in certain action fields). Political support for the process can also increase the motivation of other actors to participate in the CRA.

- Other local stakeholders should be identified and addressed. These can include, for example, larger companies, universities, environmental organisations, social organisations, energy suppliers or municipal water suppliers and disposal companies, fire brigades, civil protection and disaster relief, educational and care facilities, farmers, forestry communities. Online participation formats can be used to integrate the various stakeholder groups.

- A rough capacity and time plan should be coordinated with the interested local actors in order to prepare a participatory approach. In this context, it must be clarified whether the participation process itself should be organised and coordinated or at least supported by an external actor (professional moderator) (see Chapter 2.1.3).

- Should other actors prove to be relevant in the further course of the CRA, they should also be included in the process where possible.

Calculate available budget and secure financing
In addition to researching content-related information, the resources that are required and available for the CRA must also be determined. In addition to financial resources, this also includes the examination of human and technical resources.

- When examining the available financial and time resources and the required effort and expense, it is necessary to consider the level of detail of the assessment, i.e. the depth and breadth of the content. Less-detailed assessments can also form a useful basis for determining the need for action.

Recommendations for small municipalities and/or municipalities with limited resources

- Generally, in smaller municipalities, the implementation of a CRA is commissioned externally or at least external expertise is consulted. On the municipality side, however, it is necessary to involve those departments relevant to the climate risks i.e. environment (nature conservation, water, soil), infrastructure and buildings, planning and construction, health.

- In the event that the available quantitative data are low in smaller municipalities, qualitative research and survey methods are available. In addition, municipalities should check to what extent comprehensive quantitative data sets can be accessed, e.g. from the state offices, administrative districts or counties.

- If available, municipalities can make use of offers for consultation or technical support for a CRA at the state or district level.

- The merger of several (small) municipalities and districts in close proximity can be a good idea, especially for the implementation of a CRA. It is true that the control and monitoring of this also involves a certain amount of effort, but by bundling capacities, the planning of climate adaptation can have a solid foundation despite, for example, scarce human and financial resources.

2.1.3 Establishing a project team and determining the methods of cooperation

After the goal and desired results have been defined, the situation in the municipality has been analysed and potential contacts have been identified, the team should be assembled to further plan and implement the CRA. According to ISO 14091, the project team should consist of expert managers and specialists (e.g. for creating action plans). The aim is to set up a competent team that is empowered to make decisions. The previously identified, interested local actors outside of the municipal administration or their interests should also be represented in the project team in order to obtain application-oriented results.

- The expertise of the project team should cover all action fields potentially affected by climate risks. The responsibilities shared between the municipality and the district in various specialist areas must also be taken into account. In addition, the administrative (geo)data assessment skills (in particular GIS expertise) should be integrated.

- It is advisable to set up a core working group so that the ability to work is ensured despite the – intended – broad stakeholder participation in the overall process.

- External experts can be used in particular for specific tasks that are not within the technical area of expertise of the project team, such as the handling of climate models and data. It is up to the municipality whether external experts are consulted or integrated into the project team. In any case, the division of tasks between contractors and municipal team members should be clearly defined. When coordinating and determining responsibilities, administrative processes and personnel capacities should be taken into account.

- The responsibilities between the project members as well as regular appointments for exchange within the project team should be clearly regulated in a schedule, which will later be specified in an implementation plan (see Chapter 2.1.5).

- In order to define responsibilities, it is advisable to appoint a coordinator, e.g. a climate adaptation manager. The creation of this staff position can be part of funding programs.

- In municipalities, where different administrative levels are involved in the creation of the CRA, regular exchange can be ensured by forming a project-specific committee.

- In order to enable goal-oriented exchange among all those involved in the project team, a “moderator pool” can be formed, which can be used for professional support, including the participation process as a whole.

2.1.4 Determining the scope and methodology

The scope of the CRA, i.e. the object of investigation, and the methodology to be used are determined by the project team. For this purpose, the level of detail of the assessment is determined in such a way that the result specified in 2.1.1 can be achieved. Among other things, the spatial resolution, the climatic drivers to be included (e.g. heavy rain, heat, drought) and the period to be considered must be taken into account.

- In order to define the scope of the risk assessment, the following points should be established:

  - The area for which the CRA is to be carried out (e.g. urban or municipal area, individual districts or quarters). The dependencies that go beyond the area must also be taken into account.
  - The period to be considered in the CRA (see info box).
  - The action fields to be considered for the CRA. The (potentially) affected action fields determined when establishing the context can serve as an indication of where there may be an increased risk in the future. In addition, it is advisable to consciously address the interactions between the selected action fields.
  - The climatic drivers and climate impacts to be included.

Selecting the time period for the CRA

- The earlier risks are addressed, the sooner it is possible to manage them (with less effort and expense) and mitigate the consequences of climate change. It can therefore make sense to consider several time periods when conducting a CRA in order to enable short-, medium- and long-term planning. In this way, a reference period (e.g. the last three decades), a near future period (e.g. the next three decades) and one in the distant future (e.g. 2071 to 2100) can be considered.
- With a comparatively short assessment horizon (up to 10, 20 or 30 years in the future), climatic risks may not yet be "identifiable". However, this does not mean that there is no need for action until this point in time: On the one hand, climate change is already having an impact today and will not be stopped in the short term, even if intensive climate protection is pursued, because greenhouse gases remain in the atmosphere for many decades. On the other hand, adaptation takes time to be implemented and effective.

Recommendations for small municipalities and/or municipalities with limited resources

- Only select the action fields and systems that are particularly affected for the analysis.
- If CRAs are already available at a higher level (state, district), their data basis, findings and methodological approach can serve as helpful orientation aids for a municipal CRA.
- In order to reduce the effort and expense of a CRA in view of scarce resources and still obtain results on the local impacts of climate change, it could make sense to end the process after the "screening" step (see Chapter 2.2.1).

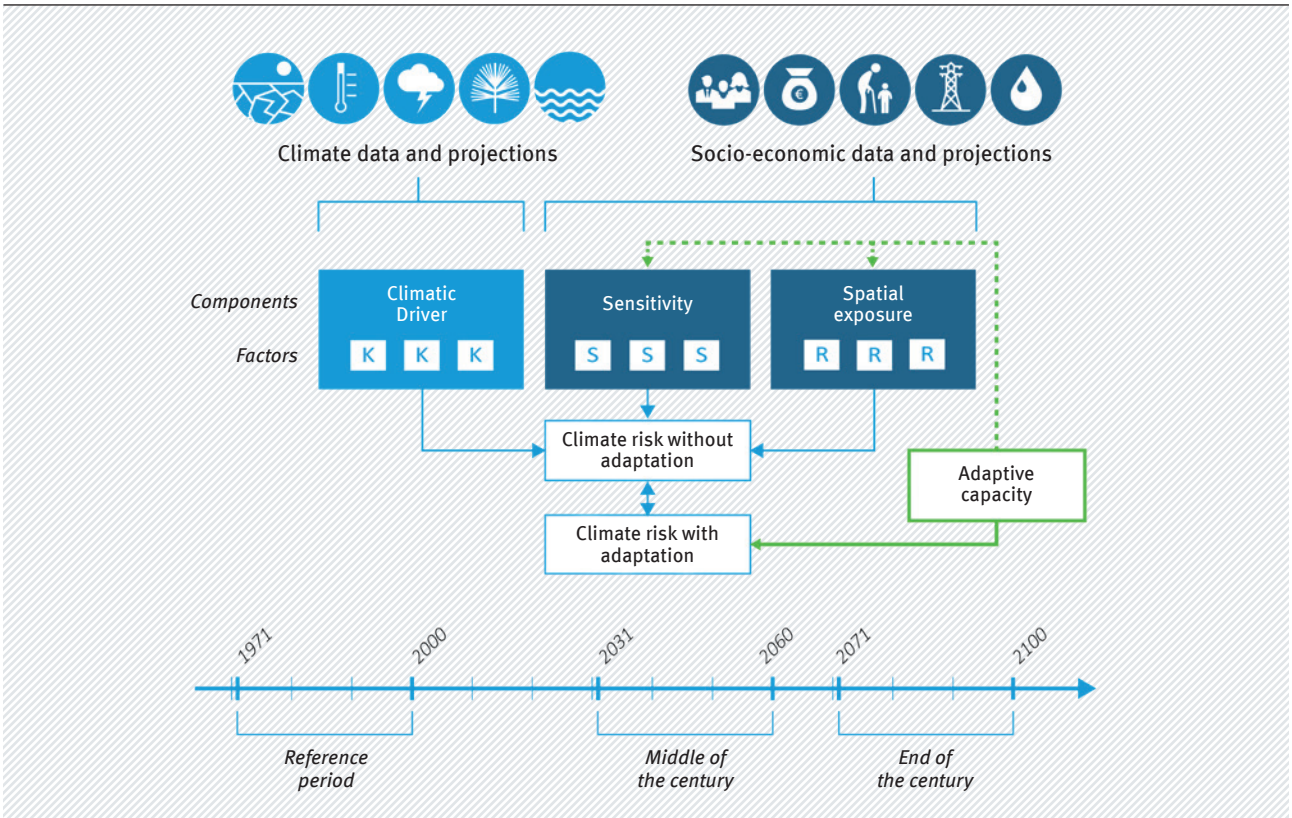
- When determining the methodology, the following should be considered:
  - With regard to the methodological concept, ISO 14091 essentially follows the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC 2014), but differentiates more clearly between sensitivity and adaptive capacity and avoids the term vulnerability (in view of its ambiguity).
  - The spatial and temporal resolution of the available data and the desired results should be considered (e.g. 100 x 100 metre grid or similar for the spatial resolution).

- Whether and which climatic and socio-economic scenarios are used is of crucial importance. As of yet, most CRA have used climate scenarios without intensive climate protection, such as the RCP8.5 scenario, which was also the case with the Climate Impact and Risk Assessment 2021 for Germany (Kahlenborn et al. 2021b).[7]
- The choice of climate scenarios is linked to questions of precaution and risk acceptance: which future should be prepared for and which risks should be lived with. This can be taken into account by distinguishing between a "less severe" and a "stronger" climate change scenario or between an "optimistic" and a "pessimistic case" in the assessment and, accordingly, either several scenarios or different percentiles (characteristics) of a climate scenario be selected (see also Kahlenborn et al. 2021b).
- The selection of climate and socio-economic scenarios as a basis for assessment is not based solely on technical criteria, but is also a normative decision. This should therefore be made as early as possible in the overall process of the CRA in order to avoid that the results of the CRA find no acceptance from the political side.
- A combined methodological approach is helpful when both qualitative information, such as expert judgment, and quantitative information, such as model data, are used to identify climate risks. A purely quantitative database is often preferred. However, it is not necessarily better than a combined approach, because in most cases there is little or no precise data. In smaller municipalities in particular, a more qualitative approach involving as many local experts as possible is conceivable.

7 Scenarios without intensive climate protection would correspond to SSP3-7.0 (IPCC 2021) in the future.

Figure 3

Overview of the methodological framework for the analysis and evaluation of the climate risk with or without adaptation of the Climate Impact and Risk Assessment 2021 for Germany



Source: Kahlenborn et al. 2021a

Key terms[8]

- Climatic driver: A changing aspect of the climate system that affects a component of a man-made or natural system (Agard et al. 2014).
- Sensitivity: The extent to which a system is adversely or beneficially affected by fluctuations or changes in climate (adapted from ISO 14091; Agard et al. 2014). Factors for sensitivity include, for example, tree species composition or age structure of the population.
- Spatial exposure: Presence of systems such as people, livelihoods, species or ecosystems, environmental functions, services and resources, infrastructure or economic, social or cultural assets in areas and circumstances that could be affected (adapted from ISO 14091; Agard et al. 2014). Possible factors to describe the exposure include, for example, population density or critical infrastructure.
- Climate impact: The potential or actual consequences of climate risks on natural and man-made systems. Climate impacts generally refer to impacts on life, livelihoods, health and well-being, ecosystems and species, economic, social and cultural values, services (including ecosystem services) and infrastructure. They can be termed consequences or outcomes and can be adverse or beneficial.
- Hazard: In the context of ISO 14091, related to climatic or climate-related physical events or trends or their physical consequences, including the climatic drivers.
- Climate risk: The potential for adverse impacts on man-made or natural systems, taking into account the diversity of values and goals associated with such systems. In the context of the KWRA 2021, the term climate risk was used based on the definition of the IPCC from the point in time at which an assessment takes place.
- Adaptive capacity: Ability of systems, institutions, people, and other living beings to adapt to potential harm, reap benefits, or respond to impacts.
- Adaptation period: Duration of time that is likely to be required for comprehensive measures to reduce climate risk to take effect, including planning and implementation.

8 Based on the glossary and methodology of the Climate Impact and Risk Assessment 2021 for Germany and in accordance with IPCC AR 5 and ISO 14091.

2.1.5 Preparing an implementation plan

Establishing an implementation plan with time-bound targets and clearly defined responsibilities is the last step in the preparation phase.

- The implementation plan should describe the upcoming tasks and define responsibilities. The plan should allow for flexibility, i.e. provide time buffers and, if possible, not rule out an adjustment in the responsibilities of those involved. The long lead times that are common in administration for the implementation of work steps should definitely be planned for.

- If the municipality has little experience with the implementation of a CRA, this can be compensated for by the expertise of an external service provider. Advanced/completed CRAs from other (comparable) municipalities can also offer orientation.

- In this step, a final coordination of the methodical procedure and the responsibilities with the parties involved (i.e. project team and other actors involved) should take place. This ensures that there is a common understanding of the methodology and objectives of the CRA.

- A common glossary also helps to establish a uniform vocabulary for the relevant components of the assessment right from the start (see info box: key terms).[9]

- In order to raise awareness of the CRA as a foundation for the development of a climate adaptation concept among local politicians at an early stage, it is advisable to plan the communication of interim results of the CRA in the overall process, e.g. by means of draft resolutions for political committees.

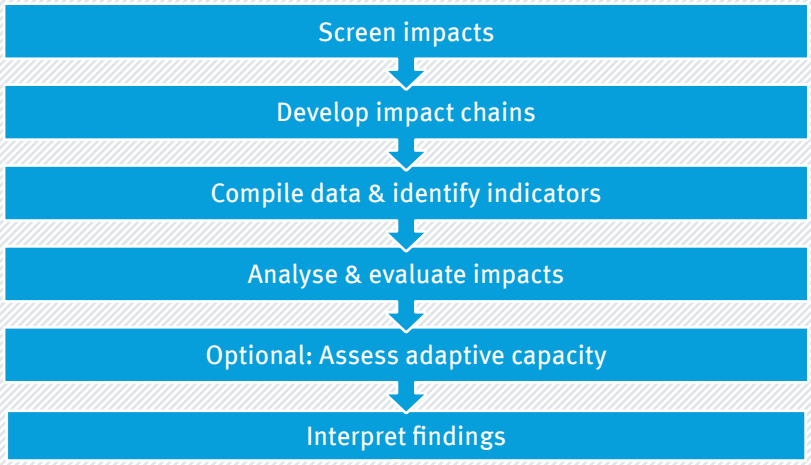
2.2 Implementing a climate change risk assessment[10]

In the implementation of a CRA, the project team analyses the effects of climate change for various action fields and then carries out an assessment of the climate risks. Optionally, the adaptive capacity can also be examined and assessed (see Figure 4).[11]

9 ISO 14091 and the Climate Impact and Risk Assessment 2021 for Germany contain suggestions for definitions that can be helpful in creating a common glossary.
10 Chapter 6 of ISO 14091
11 Notes and links to instructions for implementing a CRA methodology can be found in Chapter 3.

Figure 4

CRA steps (summary)



Source: adelphi

2.2.1 Screening and identifying impacts

The screening primarily serves to reduce complexity in order to quickly get a first impression of which action fields and climate impacts require a more in-depth assessment. The screening is therefore intended to ensure – without extensive detail – that the main effects and action fields are taken into account.

- As part of a screening, those climate impacts should be identified that are particularly relevant for the municipal level and that can exhibit high climate risks. As a first orientation, a selection based on the climate impacts examined in the Climate Impact and Risk Assessment 2021 for Germany can be found in Table 1. In the case of these climate impacts, the adaptation period and the urgency of possible measures were estimated for the federal level.
- The 31 climate impacts identified in the context of the Climate Impact and Risk Assessment 2021 for Germany with very urgent action requirements can serve as further starting points for identifying relevant climate impacts for the CRA (Kahlenborn et al. 2021b).

Table 1

Selection of possible climate impacts relevant for municipalities with high climate risks according to Climate Impact and Risk Assessment 2021 for Germany*

Note on adaptation period: The period of time that is likely to be required before comprehensive measures to reduce climate risks take effect, including planning and implementation. The assessment of the adaptation period per climate impact shown here took place as part of the Climate Impact and Risk Assessment 2021 for Germany. They relate to reducing the climate risk for Germany as a whole through nationwide measures. Different time divisions should be chosen for CRA at the municipal level and the assessment of the adaptation period should be repeated, as there is a different scope of application.

Action field	Climate impact	Adaptation period in years
Biodiversity	Change to length of the growing season and phenology	No reaction possible
	Spread of invasive species	10-50
	Loss of genetic diversity	10-50
	Relocation of areas and decline in numbers	10-50
	Damage to water-bound habitats and wetlands	10-50
	Damage to forests	>50
	Ecosystem services	10-50
Soil	Soil erosion by water	10-50
	Soil erosion by wind	10-50
Forestry	Heat and drought stress	>50
	Pest/disease stress	>50
	Forest fire risk	>50
	Utility: timber yield	10-50

* The selection was made by the authors.

Action field	Climate impact	Adaptation period in years
Coastal and marine protection	Natural spatial changes on coasts	›50
	Damage or destruction of settlements and coastal infrastructure	›50
	Overloading of the drainage facilities in flood-prone areas	10-50
Water balance, water management	Low tide	10-50
	Floods	10-50
	Overloading or failure of flood protection systems	10-50
	Flash floods (failure of drainage facilities and flood protection systems)	10-50
	Water temperature and ice cover and biological water quality	10-50
	Groundwater level and groundwater quality	10-50
	Lack of irrigation water	10-50
Construction	Damage to buildings due to heavy rain	10-50
	Damage to buildings due to river flooding	10-50
	Vegetation in settlements	›50
	Urban climate/heat islands	10-50
	Indoor climate	10-50
Industry and commerce	Reduced performance of employees	‹10
Tourism	Restriction of tourism options: impacts Lack of snow reliability on winter tourism	‹10
	Damage to tourist infrastructure and business interruptions	‹10
	Economic opportunities and risks for the tourism industry	‹10
Human health	Heat stress	10-50
	Allergic reactions to aeroallergens of plant origin	10-50
	UV-related damage to health (especially skin cancer)	10-50
	Difficulty breathing (due to air pollution)	‹10
	Effects on the healthcare system	‹10

* The selection was made by the authors.

- In addition to the high-risk climate impacts examined in the Climate Impact and Risk Assessment 2021 for Germany, other climate impacts at the municipal level may be relevant depending on the local situation, e.g. the failure of coastal protection systems or the effects of heat waves on health and wellness tourism.

- As a possible screening method, ISO 14091 proposes an initial prioritisation using a matrix (see Table 2), in which a rough and preliminary assessment of the potential climate risk for the identified climate impacts takes place. The climate impact here is a combination of a hazard as a result of climate change (e.g. the effects of heat or flooding) and an endangered system (e.g. retirement home or commercial area). The climate risk results from the assessment of the climate impact (e.g. low, medium, high). The screening can be carried out separately for the (near) past and for the (near) future, provided that assessments of the climatic developments are already available in this step. The completed matrix can serve as a basis for selecting the climate impacts to be analysed in the detailed assessment (Chapter 2.2.4).

- The results of the screening can lead to changes in the objectives of the CRA, in the composition of the project team or in the spatial or temporal frame of reference. Such changes should always be possible. As stated in ISO 14091, such things are to be expected when performing a CRA.

- The CRA can be aborted after the screening if a detailed assessment of the identified climate impacts in their development over time and their interactions as well as an assessment of the associated climate risks and adaptation potentials are to be dispensed with. This can be the case, for example, if only a few climate impacts have been identified and the planning of action is very simple.

Table 2

Example structure of a screening matrix

Systems at risk	Hazard (due to climate change)				
	Hazard I (e.g. droughts)	Hazard II (e.g. heat)	Hazard III (e.g. flash floods)	Hazard IV	**Average**
System A (e.g. public parks)	5	4	1	...	**3.3**
System B (e.g. retirement homes or the elderly in general)	2	5	4	...	**3.7**
System C (e.g. commercial area)	2	3	4	...	**3**
Average	**3**	**4**	**3**		

Source: adelphi, based on ISO 14091:2021-07
Example of a five-stage climate risk assessment: 1 (low), 2 (low-medium), 3 (medium), 4 (medium-high), 5 (high). This classification enables the identification of climate impacts with the highest risks, e.g. the climate impact "Drought effects on public parks" has a high climate risk. The average rating allows the identification of the systems most at risk (e.g. retirement homes) or largest hazards (e.g. heat).

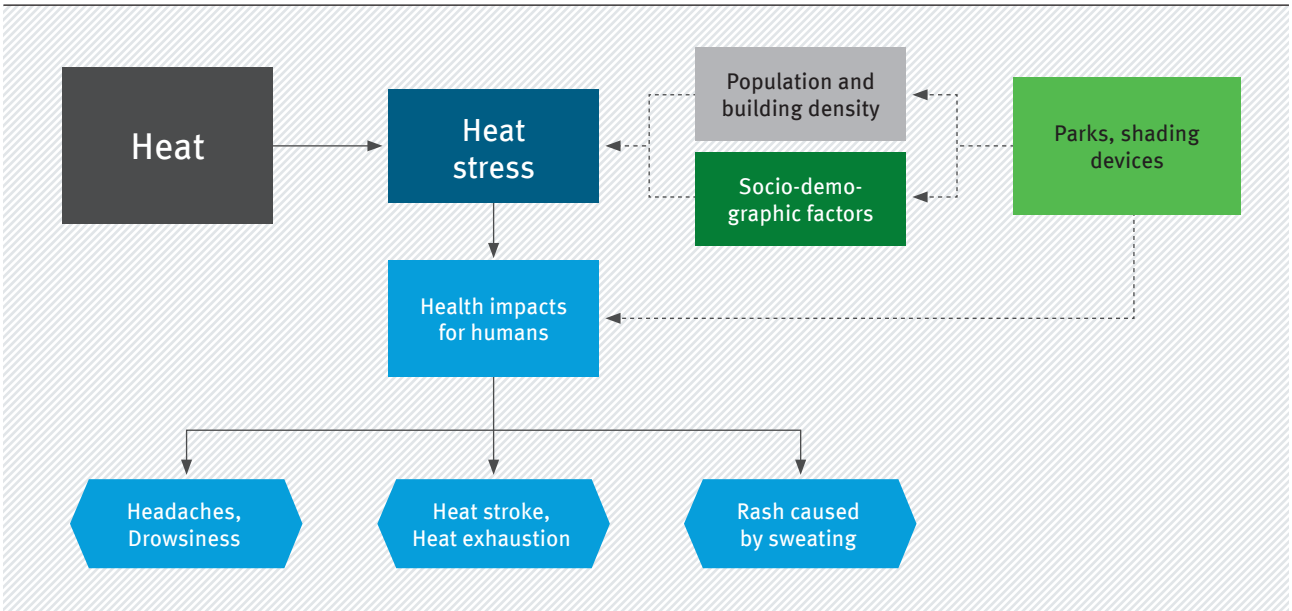
2.2.2 Developing impact chains

Based on the results of the screening, the project team can create impact chains. Impact chains help with the systematic assessment of climate risks because they provide an overview, make connections clear (e.g. possible domino effects) and allow priorities to be set. The goal is to gain a better understanding of factors that increase the risk and to develop a structure for analysing the risks based on the impact chains.

- The climatic drivers (e.g. average air temperature, heat, drought) should be used as the starting point for the impact chains. This helps determine which climate impacts (e.g. health impairments due to heat stress) result from the climatic drivers and how these are connected (interactions). Optionally, the factors of spatial exposure (e.g. building density, population density) and sensitivity (e.g. individual state of health, previous illnesses, age; also adaptation activities implemented in the past and already effective, e.g. cooling or shading measures, can influence the sensitivity) are identified and included in the impact chain. Figure 5 presents an example.
- The impact chains should reflect the local circumstances; at the same time, they should not be all-encompassing. In addition, the procedure can be easily understood using various examples of municipal or sectoral CRA that have been carried out.

Figure 5

Impact chain example



Source: adelphi

- A clear distinction between climatic driver, spatial exposure and sensitivity is helpful to determine suitable indicators for the later assessment of climate impacts (see Chapter 2.2.4) and provides a structured basis for adaptation planning following the CRA.

- The effects of climate change should be recorded separately for each action field. Those described, for instance, in national strategies like the German Adaptation Strategy (DAS) (e.g. human health, biodiversity, construction) provide a good structure for classifying the impact chains according to action fields.

- For a user-friendly approach, key questions can be asked for each action field. E.g.: "What changes have come about due to climate? What are the impacts (primary and secondary)? Who or what is affected in particular?"

- In order to analyse interactions, the project team should take into account the mutual dependencies between the climate impacts and action fields and – optionally – also consider the interactions with neighbouring municipalities and between regions. In addition to dependencies e.g. in water and energy supply, socio-economic trends and conflicts such as emigration/immigration, urbanisation, land consolidation, sealing, water and land competition should also be taken into account. Overall, as diverse perspectives as possible should be compiled.

- The interdependencies that result from the consequences of climate change are often complex. As a result, it makes sense to first focus on the most important direct effects and relevant risk factors. An iterative procedure can also be used, in which impact chains are first developed as far as possible and then supplemented if necessary after further assessment.

2.2.3 Compile data and identify indicators

After the impact chains that have been developed provide a structured overview of the existing climate impacts, the relevant information for the assessment is to be compiled in this step. This can include references to literature, statements by experts as well as data sets on climatic parameters. In addition, optional indicators for the assessment of individual climate impacts can be defined or developed. This step prepares the groundwork for the subsequent assessment of the effects of climate change.

- Qualitative information from literature analyses or expert interviews are central to a CRA at the municipal level. A lot of knowledge is already available locally (see Chapter 2.1.2). This must be recorded and analysed in a structured manner and extrapolated based on the context of climate change.

- Quantitative data, especially on climatic parameters, are relevant in order to be able to better compare current and future effects of climate change and prioritise them. Here, it can be helpful to define indicators as approximations (proxies) for complex, non-measurable conditions, e.g. the development of hot days or the length of heat periods as a proxy for assessing the health burden on the population from heat or the number of potential snow days and days with a certain amount of snow in order to be able to assess restrictions in winter tourism.

- Compiling a solid database (particularly data of a quantitative nature) for spatial exposure and sensitivity poses difficulties. Indicators can also be used as proxies for this, e.g. the proportion of the population aged 65 and over or the proportion of single-person households for an assessment of the sensitivity of the population to heat stress. It should be noted that quantitative data on relevant proxies, e.g. the future development of socio-economic or socio-demographic conditions, is subject to uncertainties. These are usually higher than in the case of climate indicators, since human actions and economic and social dynamics can be quantified less precisely and are also subject to greater fluctuations than physical relationships.

- Responsibility for data management should be organised. This defines where and how the data is collected, stored and made available.

2.2.4 Analysing and evaluating the effects of climate change

In this step, the technical analysis of the effects of climate change takes place based on the impact chains and the information compiled from literature research, interviews or workshops as well as data on climatic parameters. The aim is to obtain as comprehensive a picture as possible of the effects of climate change for the specifically defined context of the municipality. If it was decided in the preparatory phase to involve external experts, this step can also be implemented by them. After the technical analysis of the effects, they are evaluated. This is a normative step. Based on this, the need for action can be prioritised.

Detailed technical analysis

- The chosen methodology largely determines how the effects of climate change are analysed – e.g. with the help of impact models, using indicators (see also Buth et al. 2017; S. 25) and/or by means of qualitative data in the form of expert assessments – and the criteria according to which they are evaluated.

- For the analysis of the effects of climate change, the impact chains that have been developed represent a solid basis for systematically recording the effects of climate change and the affected action fields.

- As one option, the current state of research on the respective climate impacts can be taken into account in the analysis and the climatic drivers, sensitivities and exposure for each climate impact can be considered in a spatially differentiated manner.

- The results of the assessment can, for example, be broken down into the content sections background, impacts today, in the near future, and in the distant future. They can be prepared in text form and, if available, contain quantitative results in the form of tables or figures.

- The assessment results should be presented individually for each climate impact and summarised for the affected action fields. In addition, an assessment of the interactions of the climate impacts is helpful to identify structural problems, e.g. that certain climate impacts, such as water shortage in the soil, have a negative impact on many action fields.

Evaluation of the assessment results

- Based on the assessment results on the impacts of climate change, an evaluation of the associated climate risks can take place, e.g. taking into account the ecological, economic, social and cultural consequences of the climate impact, its intensity, frequency and duration or the irreversibility of the damage caused by a climate impact. As a result of the assessment, the climate impacts and, if applicable, action fields should be classified into different risk levels (e.g. low, medium, high), which enable a comparison of the climate risks and thus a prioritisation of the needs for action (see Table 3).

- The evaluation is strongly influenced by the chosen methodology and the people involved and their experience and should therefore be carried out jointly and transparently and, if possible, lead to a consensus. Any form of evaluation is complex and potentially controversial. Therefore, the legitimacy of the people involved is important, e.g. through specialist knowledge and through an order from a higher authority, in the best-case scenario from a democratically elected body.

- The assessment can be carried out by defining threshold values for each selected indicator or subject to be protected (e.g. the number of injured people) to classify the extent of damage,[12] or by normalising it into a common unit, e.g. converting the potential damage into monetary values, or using a semi-qualitative classification of the risks. In the case of the Climate Impact and Risk Assessment 2021 for Germany, a semi-qualitative classification by expert panels, which took place in a multi-stage process, proved successful.

12 See, for example, the procedure for risk assessment and setting up a risk matrix: https://www.interreg-central.eu/Content.Node/RAINMAN.html

Table 3

Example of a presentation of the evaluation results: climate risks without adaptation

Action field	Present	Middle of the century		End of the century	
		Weaker climate change	Strong climate change	Weaker climate change	Strong climate change
Biodiversity					
Soil					
Agriculture					
Forestry					
Fisheries					
Coastal and marine protection					
Water balance, water management					
Construction					
Energy industry					
Transport, transport infrastructure					
Industry and commerce					
Tourism					
Human health					

low | low-medium | medium | medium-high | high

Note: The climate risks of the 13 action fields of the German Adaptation Strategy (DAS) are shown for different periods of time according to the results of Climate Impact and Risk Assessment 2021 for Germany.

Source: adelphi, based on Kahlenborn et al. 2021c

- Once the risks have been assessed, they can be assigned to specific clusters using criteria that have to be defined. In this way, risk hot spots can be identified.

Identification of urgent needs for action

- In order to enable the prioritisation of the need for action, the climate impacts should also be assessed with regard to the urgency of adaptation. This can be derived from the adaptation period, i.e. the length of time by which climate risks can be sufficiently reduced (see Table 1). In principle, measures should be taken most quickly for climate impacts with high climate risks in the present and near future and long adaptation periods.

2.2.5 Optional: Analyse and assess adaptive capacity

In addition to the effects of climate change, a CRA can also examine the adaptive capacity. ISO 14091 recommends the analysis and evaluation of adaptive capacity to assess how risks can be reduced through adaptation, what the basic possibilities for adaptation are and how great the need for additional, potentially transformative adaptation is.

- The analysis and assessment of the adaptive capacity can be carried out in parallel with or subsequent to the assessment of the risks.

- The adaptive capacity can e.g. be analysed and evaluated by estimating the extent to which selected adaptation measures become effective and reduce climate risks (cf. Kahlenborn

et al. 2021b and Figure 3). Other approaches are also conceivable. ISO 14091 distinguishes between four components[13] and different levels of adaptive capacity[14] as a starting point for the assessment.

- The analysis of the adaptive capacity is laborious. Additional information usually has to be collected or made available. This concerns, among other things, data or estimates on various components or dimensions of adaptive capacity (e.g. knowledge, motivation, technology, natural resources, institutionalisation, human capacities, financial resources), cost estimates on specific adaptation measures, information on the combination of measures or overviews of any measures already planned and further, plausible or transformative possibilities for adaptation.

- Interactions both between adaptation measures and with other strategic goals (e.g. climate protection) or mandatory tasks of municipalities must also be taken into account. In this way, possible synergies and contradictions between individual measures and conflicting goals can be identified. This is relevant for the planning of measures following the CRA. In addition, the limits of climate adaptation should be highlighted.

13 Organisational capability, technical capability, financial capability, ecosystem capability.
14 Annexes G ("Components of adaptive capacity") and H ("Assessing adaptive capacity") of ISO 14091

- Here, too, after the technical analysis, a normative evaluation should be carried out by legitimate experts, which should be transparent and largely based on consensus.

- The level of climate risks with adaptation can be derived from the combination of the assessment of climate risks without further adaptation and the adaptive capacity (see Table 4). From the classification of the adaptive capacity in dimensions, it can be roughly deduced what kind of adaptation is needed (e.g. more knowledge, money, people).

2.2.6 Interpreting and evaluating the findings

The final step in carrying out a CRA involves interpreting and classifying the identified risks in order to provide answers to key questions formulated at the beginning.

- Existing uncertainties in the underlying information and data should be taken into account when interpreting the results and formulating options for action.

- A cross-sectoral and cross-regional consideration of the results helps to identify mutual dependencies and the most suitable measures. Since climate adaptation is also a cross-cutting issue in municipalities, various municipal departments and external expertise should be involved in interpreting the results of the CRA. It is also advisable to take gender and diversity aspects into account.

Table 4

Matrix for determining climate risks with adaptation

Climate risk with adaptation = climate risk without adaptation – adaptive capacity*					
Climate risk without adaptation / Effectiveness of adaptation	High (2)	Medium-high (1,5)	Medium (1)	Low-medium (0,5)	Low (0)
Low (1)	0	0	0	0.5	1
Medium (2)	0	0.5	1	1.5	2
High (3)	1	1.5	2	2.5	3

* Adaptive capacity operationalised using the "effectiveness of adaptation" with the range of values: 0 (low), 0.5 (low-medium), 1 (medium), 1.5 (medium-high), 2 (high); the range of values for climate risks stretches from 1 (low) through 2 (medium) to 3 (high).

Source: adelphi

- The prioritised needs for action, as the central result of a CRA, is the basis for action planning.
- It should be discussed which options for action exist at the municipal level and, if necessary, which options require cooperation with actors outside the municipality. The distribution of administrative responsibility in the various departments on several levels (city/municipality, district, federal state) must also be taken into account. Relevant local actors, possibly also from neighbouring municipalities or state representatives, should be involved at an early stage.

Recommendation for small municipalities and/or municipalities with limited resources

To quickly prioritise risks and the need for action, potential risks can be rated as "low", "medium" or "high" in a simple three-stage system. Despite the lack of details, this simplified approach can be used to identify climate impacts and action fields with high risks. In addition, an assessment of the urgency of the adaptation action is required – this clarifies in which areas climate adaptation should take place first.

2.3 Communicating the climate change risk assessment results[15]

2.3.1 Gather key findings and important messages

- The final report should communicate the goals and results of the CRA. It should highlight the key needs for action and action fields with a high level of concern.
- As shown in Chapter 2.1, the results of the CRA can be used to plan municipal climate adaptation and identify adaptation measures. In the municipal context, the reports on the results of the CRA are often embedded in the climate adaptation concepts or strategies of the municipalities.
- The results of the CRA can be used by the local government to clearly communicate how important it is to adapt to the consequences of climate change at the local level and that it is important to take action as comprehensively and quickly as possible. The results of the CRA and the subsequent needs for action should be communicated in a comprehensible manner to those responsible for implementing climate adaptation measures at the municipal and district level, even if this group of people was already involved in the development of the CRA.
- In addition to the assessment results, the possible further procedure for climate adaptation should also be included in the communication to municipal actors and citizens, e.g. how the implementation of climate adaptation could be anchored at the municipal level and which existing structures and activities could be linked.
- The transparent handling and clear naming of difficulties that have arisen during the implementation of the CRA is recommended so that the lessons learned can be used for future assessments.

15 Kapitel 7 der ISO 14091

2.3.2 Communicate results specific to target groups

- To communicate the results, it is advisable to develop various products, each aimed at a specific target group (e.g. with regard to tonality/language style, communication medium). Based on the preparatory work (Chapter 2.1), the specific goals of the communication of results should be clarified for the respective group of actors.

- The publication of a final report with a precise presentation of the data basis, methodology, procedure and detailed results is recommended for the specialist public. In addition, a summary of the main results, which clearly and comprehensibly indicates the need (and potential) for action for the concrete practical implementation of climate adaptation, can be useful for political decision-makers. Communication products such as maps or brochures for the general public can also be helpful media for communicating the results.

- In order to effectively communicate the results of the CRA to political representatives, it can make sense to integrate them with the municipal adaptation concept based on them (by default) in draft resolutions.

- When presenting the results, it is important that the results are easy to understand, that the materials are designed in an appealing way and that the key messages of the CRA are clearly presented. When communicating with non-specialists, clear, easily understandable definitions of terms and explanations of illustrations and maps are helpful. Map representations can support the development and planning of spatially differentiated adaptation measures. At the same time, maps allow results to be communicated effectively. A simplified form of representation may also be useful for this purpose.

- For the presentation of the results for local or regional actors and interested citizens, it is advisable to organise public information events such as citizen forums or dialogue-based communication formats. Risk maps (e.g. for heat, flooding or heavy rain), also as (web) GIS applications and/or interactive maps, as well as diagrams and tables can be used or examples from the given (or other) municipality can be included. As far as possible, results should be entered into existing partially/public GIS systems.

- A target-group specific online presence can supplement the communication of the results. In this way, the essential contents and results of the CRA can be presented in an easily accessible and understandable way in a condensed format.

- The results of the CRA can also be communicated to the target group via targeted information campaigns or social media messages (continuous or ad hoc) or in the form of series of topics or educational walks. In this way, the results of the CRA can contribute to not only raising the general public's awareness of the consequences of climate change and the potential for adaptation, but also to consolidating it. Especially in communication with citizens, references to the potential of individual action can be included in order to strengthen the recognition of joint responsibility.

3

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3 List of references

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