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CLIMATE SERVICES IN GERMANY

STAKEHOLDERS, CHALLENGES, FACTORS OF SUCCESS

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Deutscher Wetterdienst
Wetter und Klima aus einer Hand
DWD

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As a federally owned enterprise, GIZ supports the German Government in achieving its objectives in the field of international cooperation for sustainable development.

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Preface

The project ‘Enhancing Climate Services for Infrastructure Investments’ (CSI) forms part of Germany's International Climate Initiative (IKI). In accordance with a resolution by the German Bundestag the IKI receives backing from the country’s Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU).

The BMU has commissioned the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH to implement the CSI project from 2017 until 2020 with its partner countries and region Brazil, Costa Rica, Vietnam and the Nile Basin Initiative (NBI). GIZ’s main international implementing partners are the German Meteorological Service (DWD) and Engineers Canada.

CSI aims to empower decision-makers to make greater use of Climate Services when planning infrastructure investments and thus helps to raise infrastructure resilience. In this way, CSI also supports achieving the UN Sustainable Development Goal (SDG) 9.

To accomplish its objective, CSI brings together all relevant private and public-sector actors along the Climate Service value chain. This includes climate data providers and the stakeholders, including decision-makers and engineers, who work with this data. All activities are purposefully integrated into the National Adaptation Plans and Policies (NAPs) and (I)NDCs to promote NAP and (I)NDC development and implementation.

This study is part of the CSI project and examines Climate Services in the German context. In particular, the Climate Service value chain is investigated and those stakeholders who play a decisive role as change agents in this area are highlighted. In addition, existing challenges within the value chain are identified, which still hamper the full use of Climate Services for adaptation to climate change at the local level in Germany. Furthermore, technical, service-oriented and institutional success factors are identified that ensure positive developments in the provision and use of Climate Services in Germany. These factors and basic conditions can empower decision-makers to increase their use of Climate Services for adaptation planning. Since the landscape of Climate Services in Germany is already quite well developed in some areas, the following study presents some best practices with future potential. In the form of recommendations, these results should be trend-setting and motivating for the projects’ partner countries and region. They are intended to create incentives to promote the provision of Climate Services for adaptation planning.

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Abbreviations

BASt	Bundesanstalt für Straßenwesen
BAW	Bundesanstalt für Wasserbau
BfG	Bundesanstalt für Gewässerkunde
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe
BMU	Das Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit
BMVI	Das Bundesministerium für Verkehr und digitale Infrastruktur
BSH	Bundesamt für Seeschifffahrt und Hydrographie
CBO	Community-based organization
CSI	Climate Services for Infrastructure
DKD	Deutscher Klimadienst
DWD	Deutscher Wetterdienst
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GCOS	Global Climate Observing System
GERICS	Climate Service Center Germany
GFCS	Global Framework of Climate Services
GIZ	German Development Cooperation
ICSU	International Council for Science
ICT	Communications Technology
IKI	Germany's International Climate Initiative
IPCC	Intergovernmental Panel on Climate Change
JKI	Julius-Kühn-Institut – Bundesforschungsinstitut für Kulturpflanzen
NAP	National Adaptation Plan
NBI	Nile Basin Initiative
NCS	National Climate Service
NDC	National Determined Contribution
NGO	Non-Governmental Organization
NMHS	National Meteorological and Hydrological Service
RCC	Regional Climate Centre
SDG	Sustainable Development Goals
UBA	Umweltbundesamt
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WCRP	World Climate Research Programme
WHO	World Health Organization
WMO	World Meteorology Organisation

Figures

1. Executive summary

Within the German Adaptation Strategy, municipalities in Germany are given a special role in its implementation that is why they represent one of the largest target groups for Climate Services. Local climate information and services are therefore necessary for tailored adaptation measures in urban development or civil engineering projects. Since local authorities often do not have sufficient time or capacities for a scientific evaluation of climate data, a climate value chain has been established in Germany in which providers and intermediates guarantee the provision and processing of demand-oriented information and products.

In this study, the most important providers and intermediates as well as their linkages and contexts are presented (chapter 4). Whereas the DWD has the legal mandate as data provider and is strongly embedded in international and national networks of government institutions, private operators use, visualize or further process the data provided by federal authorities in Germany. Being part of the vertical climate value chain, these private engineering or planning companies offer a wide range of tailored climate products which are used by municipalities to carry out advisory activities for their citizens. These stakeholders are complemented by other actors within the institutions and administrative levels (horizontal climate value chain).

Chapter 5 gives an overview about the identified challenges of the climate value chain in Germany. A major challenge lies in disseminating Climate Services right up to the municipalities at the local level since the actual use of climate information requires a certain know-how which in most cases is not sufficiently available in the administrational level of the municipalities. Additionally, freely available data are usually just country- or region-specific and do not suffice as a data basis for local adaptation measures. Appropriate interaction between providers and users of Climate Services is not yet available in many cases in Germany and leads to communication difficulties in the selection and development of climate products. Furthermore, the landscape of providers of Climate Services does not appear transparent to many users, as many players have now established themselves on the market under the label of "Climate Service providers".

The study also discovered success factors for an enhanced utilisation of Climate Services for adaptation planning which are completely or partly implemented in Germany (chapter 6). As it is of great relevance for municipalities to obtain context-specific and high-resolution data and information on the specific climate in order to be able to implement appropriate adaptation measures, some (private) providers already generate data and products in high spatial resolution. Quality standards, which are maintained by state providers in Germany, guarantee a certain security in the further processing and use of these data. Positives factors regarding the service dimension of Climate Services is on the one hand the facilitated access to climate information through virtual platforms, websites and apps and on the other hand the free of charge provision of climate data by the DWD that leads to an improved dissemination of climate knowledge. Face-to-face exchange at events like conferences or workshops is of great importance to many stakeholders, especially municipalities in Germany, and appears to be an efficient format for spreading knowledge about Climate Services. The explicit statutory mandate of the DWD to take care of the meteorological protection of all important infrastructures in Germany creates clear conditions for the distribution of tasks among Climate Service providers in Germany. Besides the DWD sector- and state-specific actors and institutions are particularly important in Germany and promote the usage of climate information and services.

The study gives 6 main recommendations for an enhanced provision and use of Climate Services for adaptation planning in Germany (chapter 7.1). First of all, un unconditional access to Climate Services as well as advisory for using them is to be ensured by providers and intermediates. Users must be capable to find and use the climate information they need for their adaptation planning. In order to avoid duplication of work and to guarantee the users an easy overview, the competencies of Climate Service providers have to be intelligibly divided and bundled (by mandatory or regulatory requirements) though keeping in mind that a monopoly should be avoided. Private providers of Climate Services should complement the supply of national weather services so that Climate Services can be accessed by a broad mass of users. Despite the uncertainties that come along with future climate projections, decision-makers must learn through advisory processes how to interpret and use them in decision-making situations. More equal and balanced provider-user interactions can additionally ensure a development of appropriate climate products for every single local adaptation issue.

Referring to the provided success factors, lessons learned for the implementation of Climate Services in other regional contexts will be given (chapter 7.2). In order to provide a sustainable and efficient provision of Climate Services, relevant tasks and processes should be institutionalized and a climate value chain consisting of different providers and intermediates should be established. This institutionalisation should be guided by legal foundations and statutory mandates so that a smooth provision process can be ensured. Fruitful cooperations between providers as well as providers and intermediates are highly recommended. The benefit would be a common understanding and access to data, information and knowledge as well as an avoidance of unnecessary duplication. In order to get the best possible adaptation to local-specific effects of climate change, sector- or state-specific institutions must play a major role in the provision of local climate data for end users. Therefore, a strengthening of the provider-user interaction is mandatory for example by regular knowledge exchanges via virtual possibilities on websites as well as in apps or personal exchange at conferences, workshops or bilateral meetings.

2. Introduction

2.1. Growing Importance of Climate Services in Germany

In the light of the Paris Agreement in 2015, the importance of adaptation to climate change has increased and is now playing an overriding role in planning processes for Germany as well as for its individual states and municipalities. Together with international and national efforts to achieve more effective adaptation to climate change, the debate on the use of Climate Services for adaptation planning has gained momentum since the third World Climate Conference in 2009 and increasingly with the establishment of the Global Framework for Climate Services (GFCS) in 2012. Climate Services are intended to provide scientifically sound knowledge about climate change, based on which decision-makers at various administrative levels can decide on adaptation measures.

Since the effects of climate change vary from region to region and from sector to sector, tailor-made regional solutions are needed in addition to strategic cooperation across the states in Germany. As municipalities are particularly affected by climate change, they are identified as key actors in the German adaptation strategy. Hence, they bear a special responsibility for dealing with climate change and its consequences due to their large number of competencies and their proximity to the public. For this reason, it is of great importance to provide decision-makers at local level with sufficient and reliable climate information so that wrong decisions in adaptation planning can be avoided.

Climate Change in Germany

Climate-related natural hazards already affect Germany and will increasingly do so in the near future. In the period 1970-2014, they caused economic losses of €91bn (in 2014 values; Munich Re 2015). Around 60% of the losses were caused by storms. Floods and mass movements contributed 33%, temperature extremes, drought and forest fires caused 6% of the total damage. Geophysical events such as earthquakes, tsunamis or volcanic eruptions play a minor role in these statistics at less than 1% (Munich Re 2015). The largest single loss was caused by the floods in August 2002 in the Elbe and Danube catchment areas, amounting to €14.2bn (in 2014 values; Munich Re 2015). For the future, climate projections suggest that the already observed development will be significantly intensified, especially with undiminished greenhouse gas emissions. For example, the number of heat waves by the end of the 21st century could increase by up to 5 events per year in northern Germany and by up to 30 events per year in southern Germany in a worst-case scenario. Also, the probability of occurrence of maximum daily temperatures currently observed only about once a year is likely to rise drastically. Especially during the summer months even a tenfold increase of such events seems to be realistic. The results of the precipitation changes to be expected in the future are very uncertain and vary considerably depending on the climate model, realisation and emission scenario. Overall, it is to be expected that the trends already observed in the past will continue with an increase, above all in heavy winter precipitation. Concerning storms, a shift of the North Atlantic storm track towards Europe is likely and more strong wind events and strong gusts will occur over the North Sea and Northwest Germany as early as the middle of the 21st century. These will increase especially in winter, while there will be a decrease in summer (BRASSEUR et al. 2017).

2.2. Research objects

Relating to the international debate on Climate Services and the growing relevance of adaptation to climate change in Germany, this study will contribute to the scientific and practical discussion on Climate Services. The objective of the study is to provide an abstract of challenges and success factors of the climate value chain in Germany and to outline the main stakeholders as well as their interests and interlinkages. Having a focus on governance, the output will be an analysis of the completeness of the climate value chain in terms of lacking interlinkages of stakeholders as well as the identification of discrepancies between Climate Service offer and demand. Furthermore, key factors for an enhanced use of Climate Services for adaptation measures will be identified. According to this analysis, recommendations and lessons learned will be given. These contents are to be examined within the framework of the study based on 4 key questions:

1. Who are the main stakeholders within the value chain of Climate Services in Germany?
2. What kind of challenges can be identified along the German value chain of Climate Services?
3. Which success factors can be identified for a better utilisation of Climate Services for adaptation to climate change in Germany?
4. Which recommendations can be given with regard to communication, organisational structures, the provision and practical use of Climate Services for other regional contexts?

2.3. Methodology

(1) In order to get an understanding about the governance, challenges and success factors of the climate value chain, stakeholders from local, state as well as federal level were consulted. By interviewing these stakeholders, the climate value chain has been (re-) constructed. The survey was started with users of Climate Services on local level, mainly administrative staff of 10 different municipalities in Germany. Afterwards, 8 representatives of intermediates like research institutions, line ministries and private consultants were interviewed. As a last session, consultations with 3 stakeholders from federal level like the National Meteorological and Hydrological Service *Deutscher Wetterdienst (DKD)* and the Federal Environment Agency *Umweltbundesamt* (UBA) were conducted. This led to a more comprehensive picture of the Climate Services landscape since stakeholders were identified throughout the entire spectrum of the value chain, including data providers, intermediates and applied users.

(2) Furthermore, three conferences which dealt with adaptation to climate change and the utilisation of Climate Services were attended. To ensure an encompassing overview about platforms and situations of knowledge exchange, events on local, state as well as federal level have been chosen. The output will be a summary of successful options for exchanging and spreading knowledge about Climate Services and their utilisation for adaptation measures.

2.4 Structure of the report

The study is structured as follows: in the following *chapter 3* the theoretical background for Climate Services is provided. This includes a definition and introduction into the concept of Climate Services as well as an overview of the importance of Climate Services for adaptation planning. In addition, the theoretical framework underlying the study is presented. In *chapter 4* the most important providers and intermediates of Climate Services in Germany as well as their linkages and contexts are presented. Both, the horizontal as well as vertical climate value chain are outlined here. *Chapter 5* provides information about the identified challenges of the climate value chain in Germany. Challenges for both, providers and users of Climate Services, are highlighted. Success factors for an enhanced utilisation of Climate Services for adaptation planning in Germany are presented in *chapter 6*. This includes technical, service-oriented as well as institutional success factors which are already completely or partly implemented in Germany. In *chapter 7.1*, the study gives 6 main recommendations for an enhanced provision and use of Climate Services for adaptation planning in Germany. These suggestions refer to the governance, the technical, service-oriented and institutional dimensions of Climate Services as well as the importance of the provider-user interaction. Referring to the provided success factors, lessons learned for the implementation of Climate Services in other regional contexts are given in *chapter 7.2.*

3. Conceptualizing Climate Services for Adaptation

The climate vulnerability of people, infrastructure or housing is a prevalent vulnerability decision-makers like planners and engineers always had to deal with in the past. In the context of climate change, however, knowledge and experiences of past climate conditions and their interrelations with society may not necessarily be valid anymore for the current or future situation. The combined effects of climate change and increased vulnerability due to, e.g. land-use change, migration and infrastructure development provides unprecedented challenges to today's and future societies. Therefore, there is a growing need to understand climate, the interrelation of climate and socio-economic systems as well as climate predictions and how to better use this information to serve society's needs. This need is accounted for by many countries that attempt to develop Climate Service capabilities. A Climate Service is considered as the provision of climate information in such a way to assist decision-making by individuals or organizations in a best possible way. Although fundamental infrastructure and capabilities of climate information provision exists in many countries and regions of the world there is limited effective climate impact information for decision-making (DWD/GIZ 2018).

A Global Framework of Climate Services was established during the third World Climate Conference in order to meet these challenges and strengthen and coordinate existing initiatives and to develop new infrastructures where needed (WMO 2014a).

This chapter provides basic background information on the matter of Climate Services. This comprises definitions of Climate Services as well as information about the linkage between Climate Services and adaptation to climate change. The content of this chapter serves as the conceptual framing for the study as well as for the provided recommendations.

3.1 What are Climate Services?

Since the concept of Climate Services is relatively new, various definitions and interpretations exist. The CSI project agreed on the definition provided by the World Meteorological Organization (WMO) in the context of the Global Framework of Climate Services (GFCS). The WMO defines Climate Services as follows:

"Providing climate information in a way that assists decision making by individuals and organizations. A service requires appropriate engagement along with an effective access mechanism and must respond to user needs" (WMO 2014a).

The general WMO definition provides a rather loose delineation of the scope of Climate Services and gives thus room for interpretation. To get a better idea about the scope of Climate Services, the definition of the European Commission provides a more detailed characterization, which can be considered as supplement:

"Transformation of climate-related data — together with other relevant information — into customized products such as projections, forecasts, information, trends, economic analysis, assessments (including technology assessment), counselling on best practices, development and evaluation of solutions and any other service in relation to climate that may be of use for the society at large. As such, these services include data, information and knowledge that support adaptation, mitigation and disaster risk management" (EU 2015).

The definitions above imply three fundamental characteristics of Climate Services that also distinguish Climate Services from climate data and climate information. These characteristics

are here defined as the three dimensions of Climate Services and refer to and merge the Climate Service elements defined by WMO (2014a) *[products; support; feedback]* and International Research Institute for Climate and Society (2012) *[information; collaboration; policy & practice]*. The Climate Service dimensions are defined as follows:

- **The *technical dimension* defines the <u>usefulness</u> of a climate information product.** It refers to the content of climate information and its relevance for a specific user, user-group or sector (e.g. parameters, indices, etc.). It also refers to the contextualization of climate information with respect to scale and resolution (temporal and spatial) but also format and style of presentation of climate information (e.g. maps, graphs, diagrams, etc.). Furthermore, it comprises the quality of climate information and the provision and communication of meta-data and information on uncertainty along with the climate information.

- **The s*ervice dimension* defines the <u>usability</u> of a climate information product.** It refers to dissemination and utilization of climate information. Dissemination comprises the provision of physical access to climate information (e.g. data platforms, filter systems, etc.) but also promotion of climate information to enhance visibility and perception of the benefit for the user. A critical aspect of dissemination is the timing of delivery and update frequency of climate information. Utilization refers to the support of the user in using climate information for his decision-context. This may comprise assistance for data interpretation, decision-support tools and advice for the implementation in decision-making processes as well as training and educational material on these issues.

- **The *institutional dimension* constitutes a framework for the formation of technical and service dimension**. It refers the cooperation of relevant stakeholders that are involved in the production of a Climate Service. This implies the cooperation between various (climate) data and information providers as well as the relationship to users to guarantee usefulness and usability of climate information. But also cooperation to political stakeholders to ensure appropriate data policies (data access and availability) mandates and guidelines for the use of climate information (DWD/GIZ 2018).

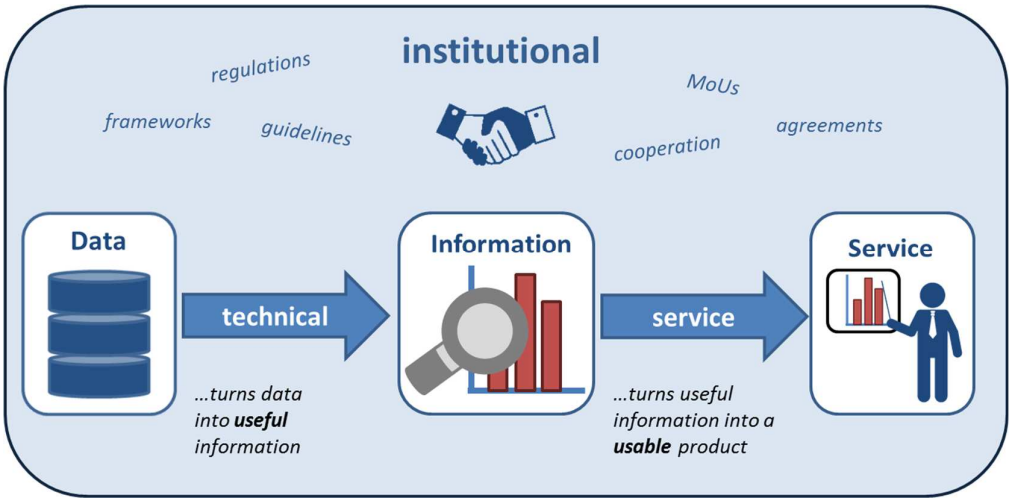

Figure 1: The three dimensions of Climate Services. The technical dimension turns data into useful information by tailoring of the data. The service dimension turns useful information into a usable climate information product by tailoring the presentation and format of the information as well as providing user-specific support and advice. The institutional dimension provides the institutional framework within a co-production of Climate Services can be realized by the cooperation of climate information providers and users (DWD/GIZ 2018).

The Climate Service dimensions suggest that a Climate Service product goes beyond the purely technical level but also includes the provision, communication and advice on climate information, the interaction with users and other stakeholders as well as the governance of climate information production and provision. Furthermore, a Climate Service product often has to be considered as a joint product, which involves the cooperation of several stakeholders. In any way, coproduction in the context of Climate Services comprises a circular (iterative and continuous) process of interaction that implies an exchange of information in both directions: from provider via intermediates to users and back. A Climate Service product cycle is an end-to-end process, which comprises the consideration of all required processing steps from data to decision-making as well as all involved stakeholders. Such an end-to-end production cycle is characterized by one or several steps of value adding which might be tailoring of data or provision of information and services, etc. to make climate information usable. This process is here described as **climate value chain** (Figure 2). The basic stakeholders of a Climate Service value chain can be classified as follows:

- *Providers*: providers of climate information collect, manage, archive and provide climate data and also basic climate diagnostic- and monitoring products as well as climate predictions and projections. Key providers on the national level are mainly National Meteorological and Hydrological Services (NMHS). Also important are academia (e.g. universities, research institutes) for model and product development as well as external data providers which provide data from the regional or global level. In many contexts the private sector may also collect relevant climate data for own interests which is, however, not systematically provided to a central database of a NCS.

- *Intermediates*: intermediates have the function of value-adding and can be differentiated in two types: (1) technical intermediates refine basic climate data or information by tailoring and/or adding external data. Important stakeholders may be impact modelers, risk managers or authorities (line ministries) who can often be found at the sectoral level; (2) institutional intermediates or boundary organizations have the function as communicators of climate information as well as advisors for decision-making. Private companies, Non-Governmental Organizations (NGOs), Community-based Organizations (CBOs) and media are important stakeholders. Another group of intermediates is “enablers” who provide basic resources like global and regional data, knowledge and capabilities (e.g. UN organizations) and funding (e.g. development banks). Intermediates are also users of climate information but with the main function as a value-adder, communicator or purveyor of climate information.

- *End-Users*: the term end-user predominantly targets stakeholders who use climate information for decision-making in a practical context from the national to the community level. In this concern, they can be distinguished from intermediates. Important stakeholders for infrastructure sectors are managers, planners, engineers or politicians (DWD/GIZ 2018).

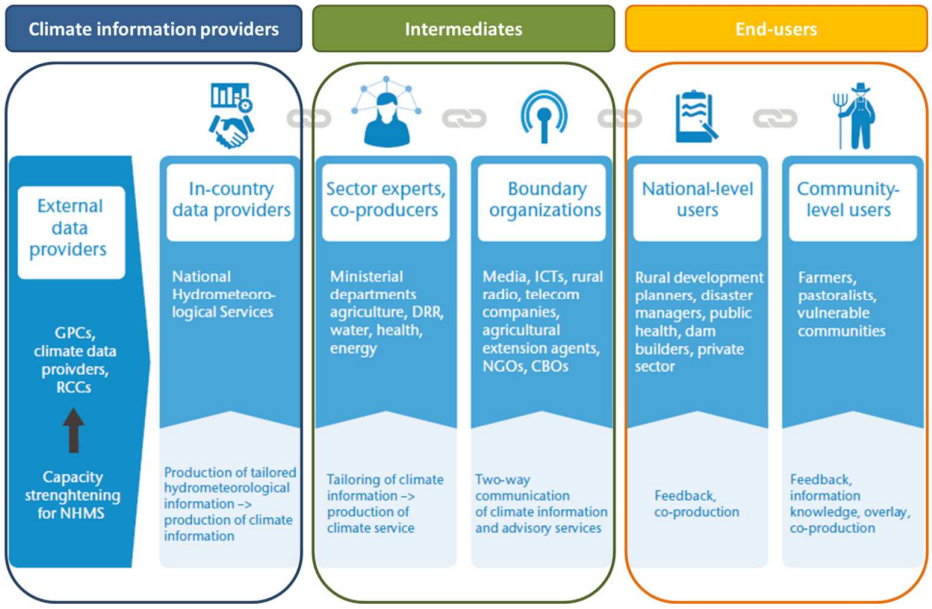

Figure 2: Concept of the climate value chain including the three major stakeholder types: climate information providers (blue box), intermediates (green box) and end-users (yellow box). The stakeholder types are subdivided by sub-types. For each sub-type examples for specific stakeholders are given (blue area) as well as their functions regarding Climate Service development and provision (grey area) (modified from WMO 2018) (DWD/GIZ 2018).

Climate value chain characteristics are context specific that often refers to individual sectors or even users or user-groups. A climate value chain is always defined by at least one provider and one user. However, the number of intermediates may vary significantly depending on the complexity of purpose and context of a Climate Service application, and furthermore, on the type of end user and his demands that reflects his capabilities and capacities to process, interpret and digest climate data and information. Besides the amount of stakeholders, the type of stakeholders may also vary or change regarding the context of the Climate Service application. Intermediates and the users often also appear in a very sector-specific context, whereas providers take a rather consistent role for Climate Service provision (DWD/GIZ 2018).

3.2 The need of Climate Services for Adaptation Planning

For planning processes in the field of adaptation measures, decision-makers at all levels need precise information on the past and future course of climate change. This information must first be available at the national level, but then must be transferred to the local level, since adaptation measures in most cases take place at the smallest spatial level (UBA 2014): *„The socioeconomic consequences of […] hazards are often most keenly felt at the local level; consequently, climate-risk management requires that decision-making be based on climate information that can be "downscaled" to a local context" (WMO 2016: 10).* At the local level, historical climate analyses, future climate projections and vulnerability analyses are therefore particularly needed in order to react adequately to climate change and implement appropriate adaptation strategies. In adaptation decision-making, Climate Services can lead to a more effective and - in the long run - cost-saving implementation of adaptation measures. Knowledge sharing, access to and availability of climate information are therefore essential to support long-term investment decisions at national, regional and local levels.

Box 1: Theoretical framework- the concept of Policy Mobilities

As this study was conducted within a scientific context, the analysis of Climate Services in Germany was embedded in a theoretical framework, named *Policy Mobilities*. Since the 1970s, and increasingly since then in the 1990s, scientists have been dealing with the phenomenon of a growing convergence of political approaches, models and instruments at the regional, national and international levels. These are processes in which policy contents (as policy instruments, programmes, institutions etc.) spread across national borders and are adopted into different regional or local contexts. To describe these processes, terms such as *policy transfer*, *diffusion* or *lesson-drawing* have been scientifically established. These partially overlapping concepts assume that domestic policy results are no longer attributable to internal factors alone, but increasingly to external influences from other national or international actors. Relating to these classical accounts of the process, which mostly emerged from political science, geographers argued that those were not extensive enough to understand the transfer of policies as a complex process that reworks places and policies in heterogeneous ways. Therefore, Geographers like EUGENE MCCANN and KEVIN WARD (2012a, 2012b, 2013) established the concept of *Policy Mobilities* which describes policy transfer from a more dynamic and more political perspective that considers recent discussions on the complex and diverse productions of spaces and places. It assumes that policies do not simply move from place A to place B but are always embedded within complex and power-laden circulations of knowledge that are intrinsically political.

4. The climate value chain in Germany

The vertical climate value chain in Germany can be divided into providers, intermediates and users. Federal institutions, state authorities and private operators play a major role for the dissemination of Climate Services. In addition, there is an interdisciplinary cooperation at all administrative levels which also generates a horizontal climate value chain.

In the analysis of the climate value chain and the actors involved, reference is made to the three-way division of the most important stakeholders into providers, intermediaries and users explained in chapter 3.1 (Figure 3). The representation of the three levels is not congruent with the administrative levels of the federal government, the states or the municipalities, but refers to the functions and areas of activity of the actors. In addition to the designation, the relationships and linkages between the various actors are to be dealt with in particular. The actors presented can be seen as “Change Agents” who have a major influence on the provision and use of Climate Services in Germany. In addition to a vertical value chain, there is also horizontal cooperation in the area of Climate Services in Germany.

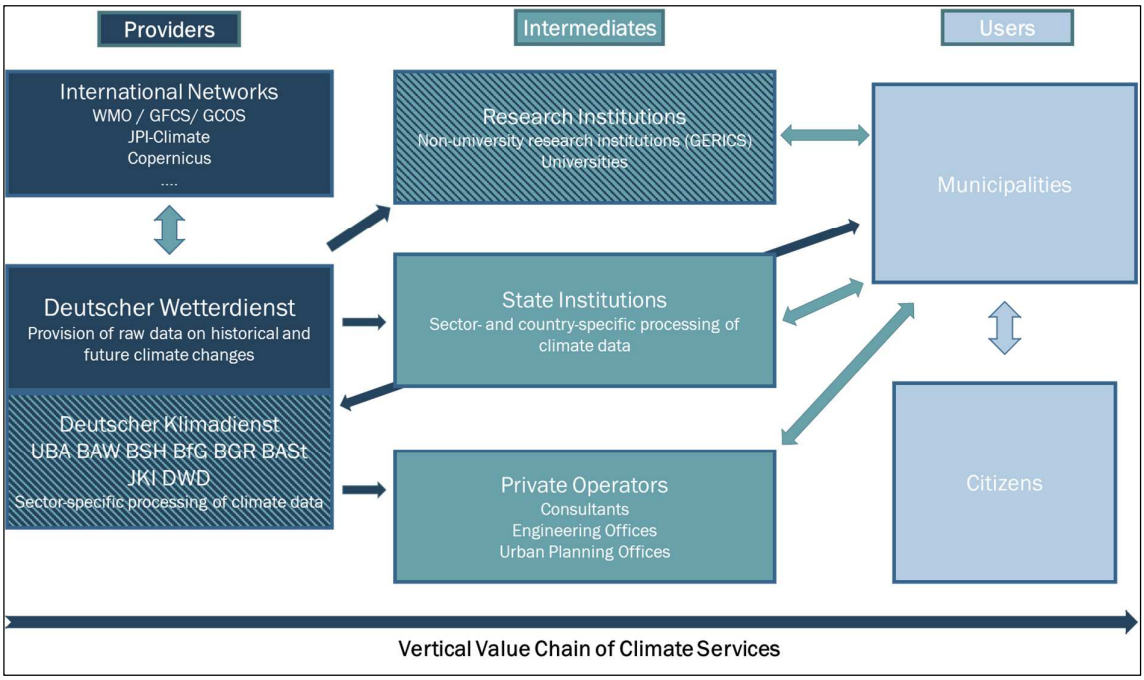

Figure 3: Actors and their linkages within the vertical value chain of Climate Services in Germany. The arrows show the direction of the Climate Service distribution. Double arrows illustrate an interaction between the actors. The Deutscher Klimadienst and Research Institutions can be assigned equally to the categories Providers and Intermediates (dashed fields) (Source: own design).

Providers

Deutscher Wetterdienst (DWD)

As in many other countries, the national meteorological service in Germany is - with an explicit statutory mandate - responsible for the provision of meteorological and climatological services to the general public or individual customers and users, in particular in the fields of transport, trade and industry, agriculture and forestry, construction, health care, water management, including preventive flood protection, environmental protection and nature conservation. In addition to climate monitoring, the DWD also conducts climate research with simulations of predictions and future projections of the climate. It also works in the field of the effects of climate change on the environment and the diverse areas of human life. At the federal level, it is located downstream of the Federal Ministry of Transport and Digital Infrastructure (BMVI) and since the amendment of the DWD Act 2017 it provides its weather and climate information mainly free of charge. In addition to research institutions and federal as well as state authorities, private operators of Climate Services benefit from the free provision of climate data by the DWD. In addition to climate monitoring and research, the DWD also works in climate and environmental consulting and prepares meteorological or climatological reports for individual associations, authorities or municipalities. The municipalities use these reports for their planning processes in the field of adaptation to climate change. To sum up, the DWD plays an important mediating role between international institutions, national research institutions and sector-specific authorities.

Deutscher Klimadienst (DKD)

The Deutscher Klimadienst (DKD), which was established in 2015 as an office of the DWD, consists of a network of 8 federal authorities (Umweltbundesamt (UBA), Bundesanstalt für Wasserbau (BAW), Bundesamt für Seeschifffahrt und Hydrographie (BSH), Bundesanstalt für Gewässerkunde (BfG), Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Bundesanstalt für Straßenwesen (BASt), Bundesforschungsinstitut für Kulturpflanzen (JKI), DWD), which are responsible for the sector-specific processing of climate data and information. The DKD aims to initiate cooperation between public authorities and agencies and to ensure that the provision of climate information and services at national level is scientifically correct, user-friendly, coherent and reliable, that unnecessary duplication is avoided and that limited resources are used in the best possible way. The various federal authorities have the task of individually preparing and evaluating the data - made available by the DWD - for their sectors and of making them available to the respective user groups as maps, reports, etc. In addition, they are to make data collected themselves available to the other authorities in the network. This means that, on the one hand, the DKD and the federal authorities assembled in it, are providers of Climate Services in Germany, but at the same time also act as intermediates.

Umweltbundesamt (UBA)

The Federal Environment Agency's (Umweltbundesamt) mission in Germany is to collect data on the state of the environment, investigate interrelationships, make forecasts for the future and use this knowledge to advise the Federal Government, such as the Federal Environment Ministry, on its policy. Another task is to inform the public about environmental issues and to be there for their questions. In addition, they implement environmental laws and put them into practice. As part of the first progress report on the German climate adaptation strategy, the German government decided in December 2015 to establish **KlimAdapt** as a separate office at the Federal Environment Agency. KlimAdapt is to provide a range of climate change adaptation services for states, municipalities, associations, companies and other forms of organisation. The aim is to enable them to independently implement climate adaptation in their areas of responsibility. The services are to be offered via a website on which current data, information and advisory services are presented. The Deutscher Klimadienst (DKD) with an office at the Deutscher Wetterdienst (DWD) and KlimAdapt of the Federal Environment Agency (UBA) form the two pillars of the national implementation of the GFCS in Germany (Figure 4).

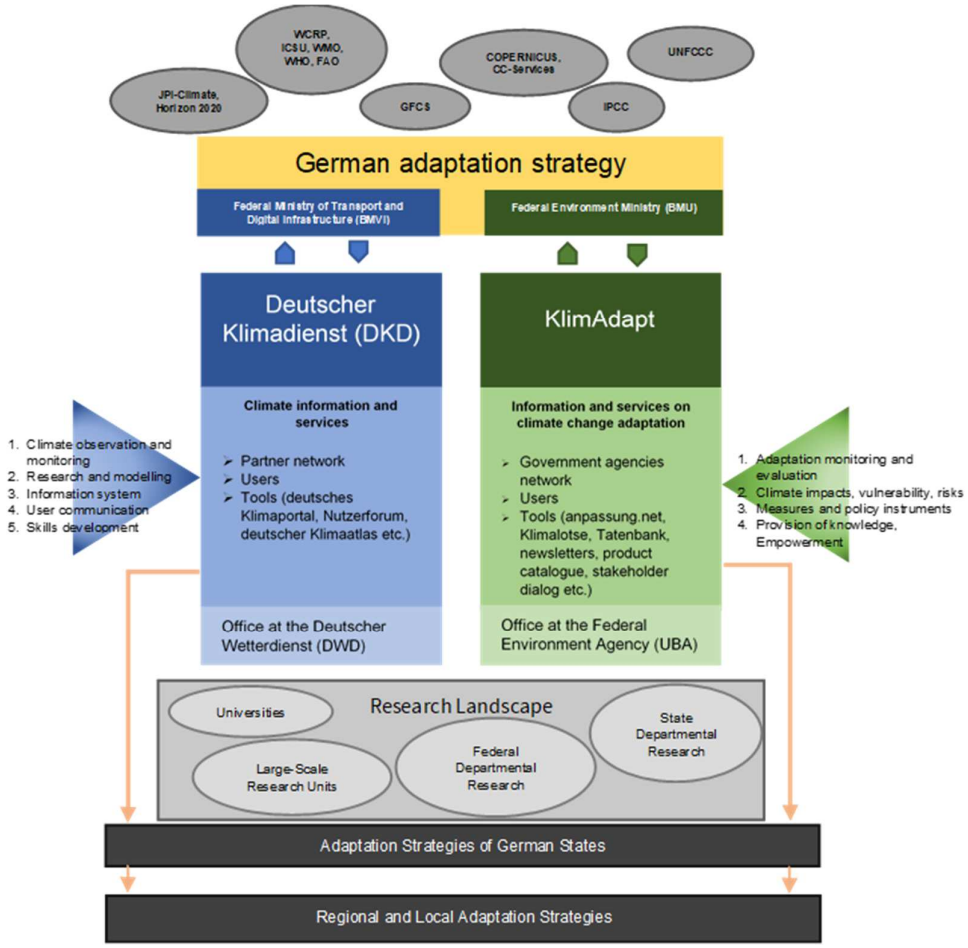

Figure 4: Organization, tasks and cooperation of DKD and KlimAdapt under the German adaptation strategy (Bundesregierung 2015)

Intermediates

Research Institutions

In Germany, university and non-university research institutions play an important role in the processing of climate information and in advising end users. When developing adaptation measures, local authorities often draw on the expertise of university staff who deal with climatological or adaptation-relevant issues in their research. The scientific expertise, which is based on the current best state of knowledge, makes universities and colleges serious partners in the development of municipal concepts. Based in part on the DWD data, universities and colleges also create their own measurements or simulations of climate change and use them in their consulting work. They are therefore predominantly important intermediates but can also act as providers of climate information and services in Germany through their own data collection. Non-university institutions are also an important part of public research in Germany. The Climate Service Center Germany (GERICS) is a major player in the area of adaptation to climate change which aims - with an innovative and novel approach - to develop Climate Service products together with end users and thus to cover the technical, service-oriented and institutional dimensions of Climate Services.

State institutions

The federal structures in Germany guarantee the states' subsidiarity with regard to climate policy. Based on the German adaptation strategy, the states are responsible for shaping their own climate policy frameworks. For this reason, state authorities, which are usually subject to the state environment ministries, are important contacts for municipal representatives who deal with climate-relevant issues. For many municipalities, the federal level seems far away, which is why offers at the state level appear more attractive and needs-oriented. Rhineland-Palatinate (Box 4), Hesse and Thuringia have centres set up exclusively for climate change adaptation. Other states also deal with climate change and adaptation in other organisational structures. German examples show how important it is in a federal state to have an institution that prepares the information for the state and passes it on to the regions, districts as well as the municipalities. This gives state institutions and centres (specialised in climate change impacts) a strong role as intermediates for the dissemination of Climate Services in Germany.

Private Operators

Adaptation to climate change at local level requires specific local climate information and data, which usually cannot be provided in full by the DWD or state institutions for reasons of time and price. Private providers of Climate Services play a major role in this respect, as they deal with urban planning issues relating to adaptation to, for example, heavy rainfall or heat waves. Sometimes several private providers work together as a consortium, each covering a different topic area of adaptation in the municipality. Private engineering or planning offices can offer municipalities a wide range of tailored climate products, most of which are sold to environmental offices, municipal drainage or civil engineering offices. These products include climate risk analysis, vulnerability analysis, heavy rainfall maps or flood hazard maps.

Users

Users should be adequately supported in decision-making processes by a user-friendly and demand-oriented provision of Climate Services. It should be noted that a wide variety of actors from different sectors (agriculture, health, disaster control, etc.) as well as the private sector are regarded as end users of these services, but this study concentrates only on municipalities as users of Climate Services for adaptation planning. Due to the federal system and the subsidiarity principle, responsibility for adaptation to climate change and the corresponding use of Climate Services in Germany lies in the hands of each individual municipality. This means that they can choose from a pool of providers and agents that take local conditions and requirements for the generation of their products into account.

Horizontal climate value chain

So far, the main focus has been on the vertical value chain of Climate Services and the actors involved. These are essential for disseminate Climate Services to the local level in order to adapt to climate change. It should be borne in mind, however, that the institutions mentioned do not only involve individual actors, but work across sectors, departments or offices. At federal level, for example, the eight above-mentioned authorities work together as the Deutscher Klimadienst (DKD) and thus form a unit as providers of Climate Services. On the other hand, however, they are independent institutions that all operate from the federal level but are also horizontally networked with each other. Similar processes can also be observed within research institutions or state institutions. Knowledge exchange and cooperation between many different actors and institutions take place at the same (state) level. Finally, such processes can also be identified at the local level within municipalities. The environmental offices are usually in charge of adaptation to climate change, but in most cases, they work together with other municipal offices. Since adaptation to climate change is a cross-cutting issue, working groups consisting of members from a wide range of technical backgrounds are established at the municipal administration level. Each department provides the existing knowledge and specific information, which is then brought together and used for adaptation planning. All in all, a horizontal dissemination of climate information and services and mainstreaming of adaptation takes place at all administrative levels in Germany.

5. Challenges within the climate value chain

Even though a distinctive climate value chain has already been established in Germany, the dissemination of Climate Services to the local level does not always proceed smoothly. Providers and users alike face challenges in the provision and use of Climate Services in Germany. To this end, joint solutions must be found.

Figure 5: Challenges within the climate value chain in Germany (Source: Own data and design).

The main actors mentioned in chapter 4 have already established a well-developed landscape of Climate Service providers and intermediates in Germany. This has resulted in particularly good cooperation between providers and intermediates, mainly due to the amendment of the DWD Act 2017, which now makes (almost) all climate data and information of the DWD freely available. Individuals and, above all, intermediates with a certain amount of know-how in this area can handle this data effortlessly and use it for their own purposes.

But a major challenge lies in disseminating Climate Services right up to the municipalities at the local level. To this end, several inhibiting factors have been identified.

First of all, a partly **user-unfriendly provision of climate information** poses great challenges for local authorities. The actual use of this information requires a certain know-how, which in most cases is not sufficiently available in the administration level of the municipalities. Abstract tools or cryptic websites where climate data can be downloaded are difficult to handle for administrators with a limited time allocation.

In addition, the freely available data are usually country- or region-specific and do not suffice as a data basis for local adaptation measures in a city or town. As a result, municipalities would have to commission a private provider of Climate Services to prepare a local and city-specific climate risk analysis. However, for **cost reasons** this is not possible for many municipalities, which is why they can only access freely available data for adaptation planning and thus run the risk of making bad investments or adaptation decisions.

The aim of Climate Services should be to develop demand-oriented climate products tailored to the local context in a dialogue between providers and users, which should support adaptation planning. This form of **interaction between providers and users of Climate Services** is not yet available in many cases in Germany and leads to communication difficulties in the selection and development of climate products. Meteorologists and users often speak different "languages", whereby users cannot formulate their own needs accordingly and providers are often unable to simplify their messages. In this connection, greater attention must be paid to the development of Climate Services in which joint solutions are developed on the initiative of the municipality (bottom-up) and in dialogue with providers.

In addition, the landscape of providers of Climate Services does **not appear transparent to many users**, as many players have now entered the market under the label of "Climate Service providers". Local authorities have difficulties in deciding which provider can meet their requirements and perform serious, high-quality work.

Furthermore, **Climate Services are mainly used only at the beginning of adaptation processes**. Decisions on climate adaptation measures are made based on climate projections and this usually ends the role of Climate Services in planning processes. However, Climate Services or climate information should support the entire process because different climate information is actually required for each planning step. Considering all these challenges, the untapped potential of Climate Services in Germany becomes apparent.

Box 2: Perceived challenges for climate services in Germany
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Experts' opinions

"How can adequate information be provided to users of climate services so that adaptation to climate change can be implemented at local level?"

"Another aspect is that the landscape of Climate Services in Germany is very diverse; it is almost impossible to keep track of all offers, which is why it has to be bundled in one place."

"What is the real application of adaptation services like? What are the users' experiences, which services are really useful? Which area really needs new customisation services?"

"You will never have optimal data, you will never have optimal information, there will always be uncertainties and especially in developing countries, where the data situation is much worse, you will have even bigger problems. So, we in Germany and Europe have the main question of making decisions based on uncertainties. So that the uncertainty is not to be regarded as disturbing."

"How can I integrate climate information into my adaptation efforts in a supportive way? I think climate change adaptation is based more on projections at the moment and then you make decisions. In my opinion climate information or Climate Services should actually support the whole process."

"Another issue concerns the generation, production and manufacture of Climate Services. Who does that? This cannot be done by one weather service alone for a whole country. Several actors have to work together and the question is how should this be organized, who assumes which role, how should the balance between the public authorities and the private sector look like, should the data be free etc.?"

"User interaction and the service concept is also a big question in science, the scientific consideration of Climate Services. And I believe a lot of creative potential is required here."

"What kind of standards for Climate Services can guarantee a certain quality?"

6. Success factors for an enhanced utilisation of Climate Services for adaptation to climate change

Conclusions for the successful provision and use of Climate Services can be derived from the established structures in Germany. Technical, service-oriented and institutional success factors that could be transferred to other regional contexts are identified.

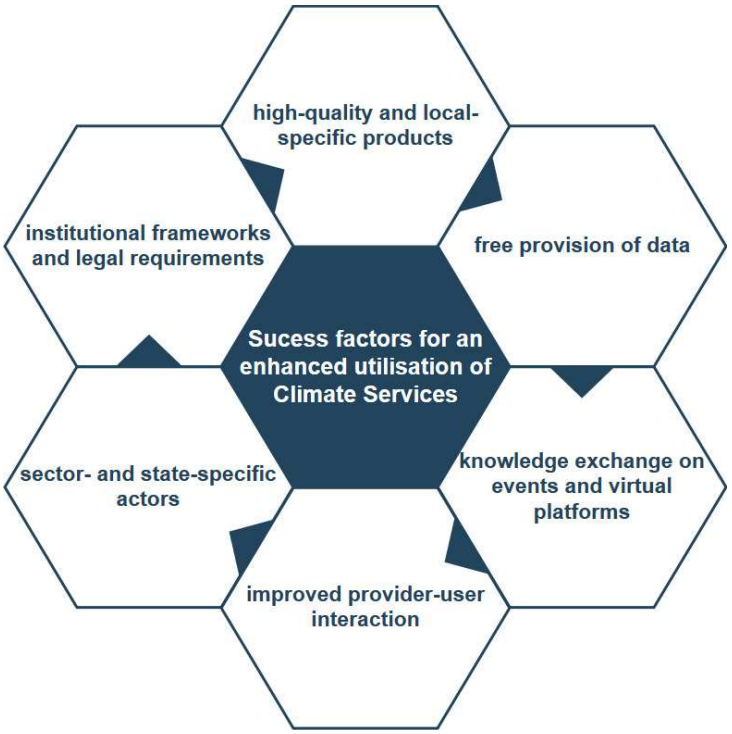

Figure 6: Success factors for an enhanced utilisation of Climate Services in Germany (Source: Own data and design).

Technical dimension

The technical dimension of Climate Services is crucial for their usefulness. It provides information on the quality and spatial resolution of the climate information and in what format it is relevant and attractive for the end user.

(1) With regard to adaptation to climate change at the local level in Germany, the **high-quality presentation of the local-specific context** is of particular interest to users of Climate Services. With a spatial resolution of the climate information of 50mx50m, 10mx10m, 5mx5m or 1mx1m, information on temperatures, heavy rainfall or wind speeds can now be displayed on a spatial level. Despite some uncertainties, especially with regard to projections, the higher the resolution, the better the decision makers at the local level can work with local data. Especially regarding urban development projects, e.g. in specific neighbourhoods, accurate data for the respective area is important, because even within a city, climatic and spatial conditions can differ. This locally specific information in microscale resolution can be displayed particularly vividly in map format and thus be used for adaptation planning.

Another decisive factor for an enhanced use of Climate Services is the **quality standard**, which is maintained by state providers in Germany. For example, the DWD, the DKD's

assembled institutions and the GERICS ensure that the data they provide are scientifically sound and correspond to the current best state of knowledge. This guarantees a certain quality and security in the further processing and use of these data. Especially for municipalities, this guarantee of reliable data is highly relevant, since it is used to inform costly infrastructure investments and is essential for avoiding maladaptation. If the municipalities can be sure of certain quality standards for climate information or products, these will be used preferentially.

Service dimension

The service dimension of Climate Services is crucial for their usability. It provides information on the physical access to climate information and what guidance is given for the interpretation of the data presented.

(2) In Germany, much of the provision and dissemination of climate information takes place **via the Internet and specialised websites, databases or apps**. Many providers, but also intermediates of Climate Services, have their own websites with climate information systems or FTP servers on which climate information can be displayed or simply downloaded. Depending on interest, the information on these websites can also be filtered by sector, region, climate variable or period and thus be adapted to specific needs. In most cases, the web pages provide a detailed breakdown of the data presented, possible interpretations are given and the data sources are explained. Other providers also operate warning apps which inform users in real time about possible dangerous situations and extreme weather events. Online access to information therefore makes it much easier to disseminate such information - compared with printed flyers or brochures - and increases the reach of Climate Services. **The provision of climate information free of charge**, as has been the case for example with the DWD since 2017, also provides an impetus for increased use of Climate Services. These free data and services can be accessed online via the DWD's website.

(3) Another way of promoting the utilisation of Climate Services for adaptation measures is via talks at events or congresses, group discussions, workshops or other ways **of face-to-face knowledge exchange**. In addition to virtual platforms, events are still the most frequently used form of information exchange in the field of climate change and Climate Services in Germany. In these situations, knowledge about historical and future climate is disseminated, information about the latest climate products, tools or websites is provided, and a dialogue between providers and users of Climate Services is promoted. Many public and private providers of Climate Services use this type of event to show their presence and to make contact with potential customers of their products and services. The face-to-face exchange at events is therefore still of great importance for many stakeholders, especially municipalities in Germany, and appears to be an efficient format for spreading knowledge about Climate Services (Box 3).

(4) Another service-oriented way of promoting Climate Services is through **improved personal provider-user interaction**. Here, the provision and use of Climate Services should be a dialogue in which providers and users can learn from each other. This is of particular interest to users, since in addition to the mere provision of climate data or products, a consultation process is also carried out by the providers during which they are informed about the use, usability and interpretation of the products. This dialogue is important for the providers as they receive feedback on their offers and can thus make them even more user-friendly. An example of this is the municipal project "KlimawandelAnpassungsCoach" of the Rheinland-Pfalz

Kompetenzzentrum für Klimawandelfolgen, in which municipalities are advised and supported by experts over several months in the initiation and continuation of climate adaptation processes. This advisory process is based on the best and most up-to-date scientific findings. This climate information is not only presented by the consultants, but also interpreted together with the municipality and the respective consequences for selected fields of action are worked out. The project, which will last several months, aims to enable municipalities to better utilize these data and, if necessary, to prepare climate data themselves following the advisory process and then use them for own purposes.

Box 3: Citizen Workshop in municipalities in Germany

Due to the federal system and the subsidiarity principle, responsibility for adaptation to climate change and the corresponding use of Climate Services in Germany lies in the hands of each individual municipality. Their tasks are not only to develop climate adaptation measures for the urban area, but also to inform their citizens about private provision for their own homes. Some municipalities have already developed special concepts and formats, for example the city of Worms in Rhineland-Palatinate, which wants to bring the topic of heavy rain and its risks closer to the citizens in workshops. By means of heavy rain maps, which were created by a private company, municipal representatives enter into dialogue with interested citizens, inform them about the hotspots of heavy rain at a 50-year event and give suggestions for possible personal precautions for their private properties. The experts usually are employees of the municipal drainage office or representatives of the environmental office of the city. After the first discussions on the basis of the maps, the experts go, together with the citizens, to the areas marked on the maps which are particularly affected by heavy rainfall events in order to get an idea of the urban planning and structural conditions on site. Together, they outline how the citizens are affected by heavy rain in these particular spots and then discuss possible structural changes to the streets and the sewerage system with city drainage staff. This citizen-oriented form of dialogue shows how Climate Services or climate products (in this case heavy rainfall maps) can be used vividly and effectively at local level to adapt to climate change. In the form of a map, complex information and data can be simplified and presented in a vivid way so that local authorities and citizens can work with it without much training or existing knowledge.

Institutional dimension

The institutional dimension of Climate Services creates the framework for the technical and service-oriented dimensions. It provides information on which actors are involved in the value chain of Climate Services and which political and institutional framework conditions promote their provision and use.

(5) Cooperation between providers, intermediates and users is one of the institutional dimensions of Climate Services. This has already been explained in detail in Chapter 4 and illustrates the large number of actors in the landscape of Climate Services in Germany. In addition to the DWD**, sector- and state-specific actors and institutions** are particularly important in Germany and promote the usage of climate information and services (Box 4). They act as a bridge between providers and users and are geared to the needs of their respective target groups. Cooperation between these centres and the DWD at federal level as well as research institutions within or outside the federal state can lead to a fruitful exchange. User-friendly processing of climate information by these sector- and state-specific stakeholders increases the usability and thus the demand of decision-makers at the local level.

(6) With the amended Act on the German Meteorological Service 2017, the Deutscher Wetterdienst (DWD) will - with an explicit statutory mandate - take care of the meteorological monitoring of all important infrastructure in Germany and research climate change and its consequences. This means that the DWD is required by law to deal with the effects of climate change in Germany and to advise politicians, industry and public authorities. This **institutional framework** makes the DWD the most important provider of Climate Services in Germany and obliges it in some way to promote their usage. In addition, this legal basis creates clear conditions for the distribution of tasks among Climate Service providers in Germany. This is a step forward towards the bundling of competencies on the provider side, which must, however, make further progress in order to maintain a certain clarity of offers for users.

Box 4: Sector- and state-specific institution: Rhineland-Palatinate Competence Centre for Climate Change Impacts

The Rheinland-Pfalz Kompetenzzentrum für Klimawandelfolgen (*Rhineland-Palatinate Competence Centre for Climate Change Impacts*) deals with the effects of climate change on all environmental and social areas in Rhineland-Palatinate, a state in the south-west of Germany. The institution is an information, advice and service centre for politicians, actors and decision-makers as well as the public.

Goals and tasks

- Research, monitoring and interlinking activities in the fields of climate change, risks and adaptation
- Implementation of research projects
- Development of regional adaptation options, e.g. for agriculture, forestry, nature conservation and the economy
- Establishment, maintenance and further development of a climate change information system
- Formation and expansion of a network with universities, federal and state institutions, associations, industry, etc.

Emergence

At the end of 2007, on the initiative of the then opposition party, the Landtag's Enquete Commission on Climate Change was set up to deal with the consequences of climate change for Rhineland-Palatinate. In addition, the Enquete Commission was to develop recommendations for action with regard to sector-specific areas, how Rhineland-Palatinate can adapt to the impacts of climate change, how existing policy can be adapted accordingly and how the right precautionary measures can be taken. As a result of this working group, it was decided to establish a competence centre for climate change adaptation.

Governance Structure

The Competence Centre is organized as a research area of the Research Institute for Forest Ecology and Forestry in Rhineland-Palatinate and technically as well as contentwise subordinated to the department of the State Ministry for the Environment, where climate protection and climate change are located. The field of climate change in Rhineland-Palatinate is divided into three institutions (State Ministry for the Environment, State Environmental Agency and the Competence Centre for Climate Change Impacts), which together form a “Climate Change Triangle”. The competence centre is financed by the Rhineland-Palatinate Ministry for the Environment. In 2011 the cost of the Competence Centre was about 750.000€ (Deutscher Landwirtschaftsverlag 2010).

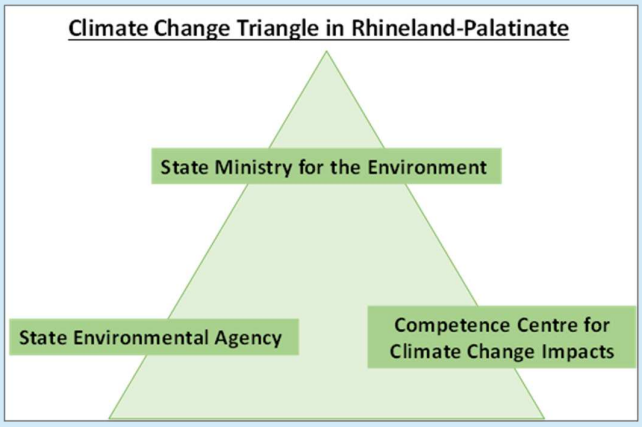

Figure 7: Governance Structure in the field of climate change in Rhineland-Palatinate (Source: Own design).

7. Conclusion and Recommendations

The prevalent climate value chain in Germany is characterised by a high number of providers, intermediates and users of Climate Services. With its legal mandate, the Deutscher Wetterdienst (DWD) is the most important weather and Climate Service provider. Due to the seriousness and high quality of the data provided, the DWD is the first point of contact for many intermediates and, in some cases, municipalities for questions relating to climate change. The DWD is embedded in international networks as well as the Deutscher Klimadienst (DKD). The DKD can be seen as a coordination platform for those federal authorities that work as Climate Service providers. These federal authorities assembled in the DKD act as a bridge between the DWD and sectoral (state) institutions and are at the same time providers and intermediates of Climate Services, as they prepare sector-specific climate information and make it available to the other institutions of the network. Other key actors are state institutions which prepare the existing data and information for the respective state in an appropriate way. They act as knowledge brokers for end users (individuals, municipalities) at the local level. Since the DWD and the state institutions cannot act alone as providers of Climate Services, private companies are becoming increasingly important knowledge brokers. Their tailor-made products are used as a basis for prevention work with citizens.

Considering the climate value chain, a gap can be identified regarding the dissemination of Climate Services right up to the municipalities at the local level. A partly user-unfriendly provision of climate information poses great challenges for local authorities. In addition, the freely available data are usually country- or region-specific and do not suffice as a data basis for local adaptation measures. As a result, municipalities have to commission private providers of Climate Services to prepare often expensive local and city-specific climate risk analyses. A productive provider-user interaction, which benefits both sides, is in many cases not yet available in Germany which leads to communication difficulties in the selection and development of climate products. Furthermore, a lack of transparency regarding the landscape of providers of Climate Services can be identified. Local authorities have difficulties in deciding which provider can meet their requirements. In addition, Climate Services are mainly used only at the beginning of adaptation processes but should actually support the entire process because different climate information is required for each planning step.

7.1 Recommendations for the German context

Since this study also intends to be useful for future processes in the field of Climate Services for adaptation planning in Germany, recommendations will be given in this context. These reflect the statements of the interview partners as well as own conclusions:

1. For all municipalities in Germany to be able to use Climate Services for adaptation planning in the future, the sustainability of the dissemination must be secured. To this end, access to usable and useful climate information must be guaranteed and municipalities must be enabled to make appropriate use of Climate Services through advisory processes - whether in personal exchange or with virtual guidance.
2. A clear division of roles among the Climate Service providers must take place in order to avoid duplication of work and to guarantee the users an easy overview of the competencies. This must go hand in hand with a bundling of competencies on the provider and intermediate side in order to minimise the lack of transparency. However, a possible monopoly of Climate Service providers should be avoided, as otherwise the quality of the services could fall considerably.

3. In order to make Climate Services usable for adaptation planning for a broad mass, not only the national weather service can play a superordinate role but also the role of private providers must be taken into consideration. To guarantee a certain seriousness, possible standardisations or accreditations must be considered in the future, which should act as an orientation aid for users.
4. Another important measure is to enable users to make decisions based on uncertainties. Every projection for the future climate contains uncertainties which need to be minimized but can never be completely eliminated. Decision-makers must learn through advisory processes to be able to assess uncertainties and not be discouraged by them in decision-making situations.
5. In the future, bottom-up approaches should be utilized to develop appropriate climate products for every single local adaptation issue. Each individual question within the adaptation process (awareness raising, climate risk analysis, identification of adaptation options, evaluation of measures, etc.) must be accompanied by different, tailored information and products. The intensive exchange between providers and users and an increased consideration of the term "services" will be essential in this regard.
6. In addition, more course needs to be set for the institutional framework conditions for the provision and use of Climate Services in order to support the climate value chain and thus the dissemination to the local level. Regulatory requirements for the mandatory use of Climate Services in decision-making processes or a reporting obligation on adaptation to climate change can be considered.

7.2 General recommendations

Even though Germany is still facing challenges in the area of Climate Services, the identified success factors (chapter 5) can serve as good examples for actions in other regional contexts:

1. **Establishment of a climate value chain:**
   In order to provide a sustainable and efficient provision of Climate Services, relevant tasks and processes should be institutionalized. This implies an expansion of the prevalent National Climate Service by integrating relevant climate information providers as well as sectoral line ministries or authorities. The provider side should be supplemented with different intermediates which process the climate information and make it available to the end users.
2. **Establishment of an institutional framework:**
   Legal foundations and statutory mandates can be directive for the work of federal institutions like a National Meteorological Service. They provide clarity about the tasks and requirements which must be fulfilled by the respective institution. In addition, they help to differentiate the areas of responsibility from those of other Climate Services providers. A legally mandated free provision of data can enhance a timely and qualitative production, provision and use of Climate Services.
3. **Establishment of a network of sector-specific providers:**
   As the example of the Deutscher Klimadienst (DKD) in Germany shows, an effective sectoral dissemination of climate information can be achieved if different federal institutions work together in a cross-sector network. The benefit would be a common understanding and access to data, information and knowledge which is relevant for climate risk issues and adaptation to climate change. Products and knowledge which are being produced by any of the partners would be made available to all partners.

Furthermore, resources and capabilities can be shared to produce costly and complex tasks. Unnecessary duplication can be prevented.

4. **Data exchange between providers and intermediates of Climate Services:**
   For an effective provision and dissemination of Climate Services, an exchange not only between providers but also with corresponding intermediates is of great relevance. Intermediates like research or state-specific institutions can make their own (often more locally specific) data available to the providers and in return work with the providers' climate data. A cooperation of these stakeholders is highly recommended.
5. **Spatial- or sector-oriented provision of climate information and data:**
   Adaptation to climate change requires high quality, high resolution as well as sector- and local-specific data. Although general country-specific data are of interest for adaptation measures, they only can be of little or no help for local challenges. Therefore, sector- or state-specific institutions play a major role in the provision of local climate data to and the consulting of end users. These intermediates can concentrate on a limited geographical area and focus their resources and competencies on this in order to produce high-quality data and products.
6. **Establishment of platforms for knowledge exchange:**
   In order to promote the effective provision and use of Climate Services, a regular exchange between providers, intermediates and users must be ensured. In addition to virtual possibilities on websites or in apps, a personal exchange should take place at conferences, workshops or bilateral meetings. These events promote an intensive exchange between the various stakeholders, in which differences between the supply and demand of Climate Services can be discussed. These discussions can then lead to ideas for a development of sector-specific climate information products together with sectoral users and research partners. Strengthening the provider-user interaction is highly recommended.

8. Outlook

The results of the present study should raise awareness of the importance of Climate Services for adaptation to climate change, especially in times when climate change is already taking hold in the German context. This makes it even more important to create framework conditions for improved use and thus dissemination of Climate Services in order to be able to respond better to future climate changes. The providers, intermediates and users of Climate Services identified in this study are nothing but a snapshot of the current implementation of the GFCS in Germany. In the coming years, international and national political processes will continue to develop and new actors and stakeholders within the field of Climate Services may emerge. In order to be able to guarantee regulated processes and organisational structures in the future, the foundations of national implementation must be laid today. The above-mentioned recommendations can serve as helpful suggestions for German implementation. Germany can also act as a pioneer for other countries and regions of the world that are still in the early stages of implementing Climate Services. Especially in view of the changing climate worldwide, the support of and cooperation with partner countries are of high relevance for the coming years. In this regard, the main aim is to exploit local potential, make use of existing structures and work together on creative and innovative solutions tailored to the specific context.

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