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Assessing Vulnerability to Heat Waves and Heavy Rainfall at a Community Level



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Assessing Vulnerability to Heat Waves and Heavy Rainfall at a Community Level
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**Assessing Vulnerability
to Heat Waves and Heavy Rainfall
at a Community Level**



Christoph Unger
President of the German Federal Office of Civil Protection
and Disaster Assistance, BBK

Dear Readers,

This guide is based on the findings of a three-year research project with the title "Kritische Infrastruktur und Bevölkerung(sschutz) im Kontext klimawandelbeeinflusster Extremwetterereignisse (KIBEX)" (English title "Critical infrastructure and population/civil protection in the context of climate change related extreme weather events"). The project was funded by the German Federal Office of Civil Protection and Disaster Assistance which also provided specialist support.

The KIBEX project developed methods for analysing the vulnerability of the population and critical infrastructures to the two natural hazards heat waves and heavy rainfall which are presented in the guideline. The findings of the analysis introduced can be used for example to optimise evacuation plans, supplement risk analyses and as input for minimal concepts for supplying the population with electricity. The guideline's suitability for practical application is guaranteed on the one hand by the four methodological pillars of scientific analysis, i. e. literature analysis, expert interviews, household surveys and round table discussions. On the other hand, participants from the Cities of Cologne, Karlsruhe and Wuppertal and from the District of Stendal contributed to matching the results with their needs and conditions on the ground. I would like to thank them at this point for their enthusiastic assistance. The many practical examples in the guideline demonstrate good ways of applying individual steps in the methodology.

Naturally, like other municipalities and rural districts in Germany, the partners mentioned have not only been working on extreme weather events since we began detailed discussions on the effects of climate

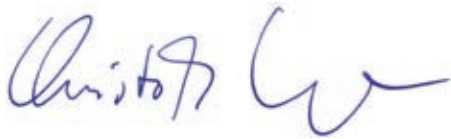
change. The necessity of dealing with extreme weather such as heat and heavy rainfall actually belongs to the basic tasks of all those responsible for civil protection. This challenge is faced by municipalities, Länder and the Federal Government within their specific remits. While the Länder are responsible for precautionary measures and for dealing with damaging events, the Federal Government primarily plays a supportive and advisory function.

To maintain and perhaps further optimise the very high level of prevention and handling of extreme weather events in Germany, changes in hazard situations must be identified early, monitored continuously and translated into required action. The stakeholders in civil protection need to know what the extreme weather events mean locally for citizens and the infrastructure on which they rely. How do the extreme weather events change and how does the vulnerability of the public and the infrastructure change?

This guideline points out opportunities to identify areas which are particularly affected using the resources available in the municipality. Indicators show, where the vulnerability of population and infrastructure lies. Even though the guideline focuses on an analysis of problems to determine vulnerability, initial recommendations for action are given in many places. The comprehensive check list for recording vulnerability to power failures provides a particular added benefit for practice. It can also be used without the guideline and is a basis for municipalities and for managers who are looking in detail at the dependency on electricity and the necessity for minimal supply concepts for the first time.

This outcome could not have been achieved without the assistance of many able partners from the scientific community, local government and the fields of energy supply and engineering who contributed to the expert workshops and gave further advice to the KIBEX research project. Particular thanks are due to the Institute for Environment and Human Security of the United Nations University (UNU-EHS) which undertook the project management. Major support was provided by the project partners from the Potsdam Institute for Climate Impact Research and the German Aerospace Center.

I wish you interesting reading.



Christoph Unger,
President of the German Federal Office of Civil
Protection and Disaster Assistance, BBK



Prof. Dr. Jakob Rhyner,
Director of the United Nations University
Institute for Environment and Human Security (UNU-EHS)

Dear Readers,

Global climate change and the respective rise in the average global temperature will lead to an increase in the intensity and frequency of extreme weather events. These will in some regions result in the more frequent occurrence of heat waves and heavy rainfall events which could affect the population both directly and indirectly through the failure of infrastructures. Effective protection and preventive measures must be developed and implemented to deal with them. It is increasingly obvious that integrated and holistic risk reduction strategies are necessary both for preventative civil protection and for urban and regional development. In this context, recording the vulnerability of the population and critical infrastructures is an important key to the development of appropriate action strategies.

This guideline "Assessing Vulnerability to Heat Waves and Heavy Rainfall at a Community Level" shows in a clear and easy-to-understand manner how the abstract concept of vulnerability to heat waves and heavy rainfall events can be translated into specific indicators and criteria and appropriate assessment procedures. Although the guideline is primarily directed at professionals in the areas of civil protection, municipal administration and land use planning at local level, it can nevertheless provide important pointers for research and for interested members of the public who wish to look into recording, measurement and evaluation of risks and vulnerabilities to heat waves and heavy precipitation.

Using practical examples, the guide illustrates the implementation of the vulnerability concept to the specified natural hazards. Besides the assessment of the direct vulnerability of the population, the concept is

also applied to potentially susceptible infrastructures whose failure can directly impact on both the population and the emergency services. In order to develop appropriate action strategies, the components of vulnerability are operationalised and systematically applied. This comprises: a) exposure to the natural hazard, b) susceptibility and c) the coping capacity of the exposed element.

Clear differences are apparent for each component in this respect, as is illustrated by the exposure to heat waves which is significantly more pronounced in inner city areas due to the *urban heat island effect*. In terms of susceptibility towards heat stress, those people who e. g. suffer from heart and circulatory problems or lung disease are more vulnerable while people who have already experienced a heat wave can often better deal with it and therefore have a higher coping capacity.

The development of this guideline has created an instrument for municipalities which not only offers support for adapting to climate change through preparing for more frequent extreme weather events but also provides a key tool for reducing municipal vulnerability and makes an important contribution to disaster management. The publication's relevance to practice is due to the numerous partners who were involved in the development and discussion of this guideline.

The guideline should provide a stimulus for discussion and the development of strategies for managing risk in connection with climate change and the changing demographic and technical contexts. It should provide a contribution to networking and coopera-

tion between the various players and also supply practical information on assessing the vulnerability of municipalities and examples of best practice.

A handwritten signature in black ink, appearing to read "J. Rhyner". The signature is written in a cursive, slightly slanted style.

Prof. Dr. Jakob Rhyner,
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First, we would particularly like to thank the German Federal Office of Civil Protection and Disaster Assistance (BBK), which not only made the project possible through financing but also contributed to the content and provided support in the form of much valuable information.

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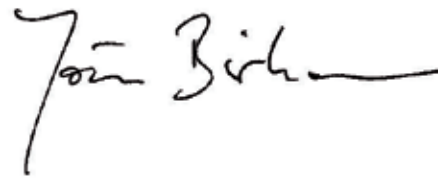
¹ We would like to convey our particular thanks for the close and helpful cooperation in assessing the depressions in the municipal area of Wuppertal and for the provision of data, text and figures for Chapter 5.

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For the team of authors

A handwritten signature in black ink, reading "Jörn Birkmann". The signature is written in a cursive style with a long horizontal stroke at the end.

PD Dr.-Ing. Jörn Birkmann

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Vulnerability assessment of the population and critical infrastructures to heat waves and heavy rainfall

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I. Chapter

Summary

This guideline presents options for assessing vulnerability of the population and critical infrastructures to two natural hazards, namely heat waves and heavy rainfall. The reader is introduced to the assessment one step at a time and given preliminary advice and recommendations for protective and precautionary measures.

The guideline is intended to assist representatives of municipal administrative bodies (e. g. environment and spatial/city planning offices) in their work and also provides a good source of information for operators of infrastructures (e. g. suppliers of electricity and water). Overall, both the assessment of vulnerability and the implementation of vulnerability reduction measures require close cooperation between different offices and authorities – the administrative bodies and infrastructure operators, the emergency services (e. g. the fire brigade and rescue services) and also the individual citizen.

The guideline is a product of the BBK funded research project *Kritische Infrastrukturen und Bevölkerung (-schutz) im Kontext klimawandelbeeinflusster Extremwetterereignisse (KIBEX)* (Critical infrastructure and population/civil protection in the context of climate change-related extreme weather events). Another guideline „Abschätzung der Verwundbarkeit gegenüber Hochwasserereignissen auf kommunaler Ebene“², (Assessing Vulnerability to Flood Events at a Community Level) has already been published in German as part of a previous project. In both guidelines, the vulnerability assessment method is based on the same understanding of vulnerability comprising three components *exposure, susceptibility and coping capacity*:

- **Exposure:** the physical *exposure* to a natural hazard
- **Susceptibility:** likelihood to suffer harm due to a natural hazard event

- **Coping capacity:** availability of resources and capabilities to minimise the negative effects of natural hazards

The guidelines also have a similar structural layout, making them suitable as a common working basis for the municipalities. However, they necessarily differ in their methodological analysis as they recommend a hazard-related approach (e. g. vulnerability to floods or vulnerability to heat waves). This means that specific features of the particular natural hazard of relevance are taken into account in assessing the vulnerability components.

Firstly, the spatial differences of the natural hazard impact are identified to determine the exposure of the population or components of critical infrastructures. Within the scope of this guideline, the factors which determine variation in exposure to heat waves and heavy rainfall events are considered. In the case of heat waves, these factors - particularly in cities - are based on the differentiated urban heat island effect (UHI). In contrast, topographical features, especially depressions, are of key importance for examining exposure to heavy rainfall. Ideally, there are already available studies and data on the urban heat island effect, otherwise an assessment can be made using weather station or satellite data. In the case of heavy rainfall, digital terrain models can be used to identify depressions as potentially flooded areas.

The next step involves the assessment of susceptibilities and coping capacities. As with exposure, the analysis of these two vulnerability components can be used to derive targeted protective and precautionary measures for both, the population and critical infrastructures. Indicators for the susceptibility and coping capacity of the population are for example the percentage of the population aged 65 and older and living alone or the percentage of the population who have experience of dealing with heat wave events (represented by the period of residence). Data for these indicators is available in the municipalities

² Birkmann, J., Dech, S., Gähler, M., Krings, S., Kühling, W., Meisel, K., Roth, A., Schieritz, A., Taubenböck, H., Vollmer, M., Welle, T., Wolfertz, J., Wurm, M., Zwenzner, H. (2010a): Abschätzung der Verwundbarkeit gegenüber Hochwasserereignisse auf kommunaler Ebene. Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK). Praxis im Bevölkerungsschutz, Band 4. Available at: http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Praxis_Bevoelkerungsschutz/Band_4_Hochwasser-Kom-Ebene.pdf?__blob=publicationFile.

at a small-scale level (e. g. city district). Indicators which can be derived from generally available data usually provide a preliminary point of reference for vulnerability. However, additional *criteria* based on data that may only be available in part or that may need to be collected from specific surveys should be considered (e. g. people living in top floor flats; structural precautions to prevent the entry of water; the availability of natural hazard insurance). Such criteria can be incorporated in the vulnerability assessment as far as possible and should be taken into account particularly for recommendations, information for the public etc. (see also Sections 4.2 and 5.2).

The susceptibilities and coping capacities of critical infrastructures are determined by various sector specific factors. The vulnerability assessment of critical infrastructures here is carried out for socio-economic service infrastructures (e. g. hospitals and nurseries³) and electricity supply. Both sectors were selected as

an example in the development of analysis methods due to their role as basic infrastructures. While susceptibility and coping capacity of socio-economic service infrastructures are mainly determined by the physical conditions of their clients, susceptibility and coping capacity of electricity supply are determined by technical and organisational aspects. For example, power generation technologies and their dependence on cooling water are important factors, but also technical and organisational capabilities to replace components affects the overall vulnerability of the supply system.

Finally, a comprehensive list of criteria was developed in order to assess the potential effects of power failures on municipalities. The criteria focus on the vulnerability of the main stakeholders – the emergency services, the population and the operators of critical infrastructures – to such failures.

³ Nurseries are no critical infrastructure as defined by the BMI. Their failure does not lead to a significant disruption of public safety and security. At the local level however, they represent very vulnerable facilities and would require high civil protection capacities when e. g. flooded.

II. Chapter

Background information

2.1 The KIBEX project: Critical infrastructure and population/civil protection in the context of climate change-related extreme events

The project *Critical infrastructure and population/civil protection in the context of climate change-related extreme events* (KIBEX), was funded by the German Federal Office of Civil Protection and Disaster Assistance (BBK). It was carried out by the United Nations University Institute for Environment and Human Security (UNU-EHS) in cooperation with the Potsdam Institute for Climate Impact Research (PIK) and the German Aerospace Center (DLR). In addition, cooperation with partners from the cities of Karlsruhe, Wuppertal and Cologne and from the district of Stendal enabled the incorporation of knowledge and experience from practice. KIBEX is a follow-up project of the project *INDICATORS for assessing vulnerability and coping potential using the example of water-based natural hazards in urban areas* which generated the guideline "Abschätzung der Verwundbarkeit gegenüber Hochwasserereignissen auf kommunaler Ebene" (assessing vulnerability to flood events at a community level)⁴. While the INDICATOR project focused on flood hazards in relation to critical infrastructures (CIs), population and environment, the KIBEX project focuses on the vulnerability of the population and CIs to heat waves and heavy rainfall. First of all, the direct effects of each natural hazard were analysed, but *second-order degree* or *indirect effects* of those hazards, e. g. through the failure of infrastructures were also considered. The public's steadily increasing dependency on infrastructure services and a lack of awareness of these could result in far-reaching consequences following failures of CIs. Thus, the guideline presents corresponding methods for assessing the direct and indirect vulnerability of municipalities.

The guideline is based on the findings of the KIBEX project. This rests on four different methodological elements which were used to derive the methods described here:

1. A comprehensive analysis of existing research, as well as carrying out
2. Interviews with experts,
3. Household surveys,
4. Group discussions and round tables.

The experts included

- Representatives from the emergency services, e.g. from the partner cities of Cologne, Wuppertal and Karlsruhe as well as the district of Stendal
- Representatives from local public utility companies dealing with water and electricity
- Representatives of local authorities such as environment, highways, health offices and water boards
- Representatives from the scientific community

In the course of the project a total of around 50 interviews were carried out with experts, providing important general information on existing interdependencies of various CIs and population and func-

⁴ Cf. footnote 2: Birkmann et al. 2010a.

tional chains in the context of heat waves and heavy rainfall.

In order to validate the findings and to evaluate their applicability, round tables and group discussions with representatives of the partnering municipalities

were held throughout the project. A total of 8 round table discussions were held in Karlsruhe, Wuppertal and Stendal and the results were incorporated in the further development of the project. By doing so, a high relevance of the research findings for the praxis is ensured.

2.2 The guideline in the context of national and international processes

As part of its vulnerability assessment, the guideline refers to various trends that will affect the task of civil protection in the future. The main topic discussed here is climate change. However, changing technology and increasing (inter)dependencies between CI systems also play an important role that have to be considered when assessing CI vulnerability. All these trends occur on a global scale but they can manifest in very different ways at a local level. While this guideline refers to districts in Germany, assessment methodologies might be transferred to other regions in Europe and beyond.

Climate change is a current global challenge which, among other things, is changing the frequency and intensity of certain extreme weather events. The IPCC concludes in its Special Report (IPCC 2012) that duration, frequency and/or the intensity of heat waves is very likely to increase, in particular for rural areas. For heavy precipitation events, an increase in frequency is likely in *many* regions. For specific events, Coumou and Rahmstorf (2012) found a clear evidence for the relationship between the increase of heat waves and heavy precipitation extremes and anthropogenic influence on the climate. Coumou et al. (2013) calculated five-fold more frequent extremely hot month compared to the expected occurrence without the long-term global warming.

The German adaptation strategy already refers to climate related changes and the resulting requirements for adaptation. It emphasises that climate change may have varying effects in different areas and therefore, many measures have to be taken at the local and regional level (Bundesregierung 2008). CIs such as the electricity and water industries are among the areas affected by the consequences of climate change where actions are necessary. In this context, civil protection is mentioned explicitly as a cross-sectional area of the affected sectors, including the protection of critical infrastructures. Although CIs are largely in private ownership, cooperation e. g. with civil protection agencies specifically during emergencies is

crucial for a reliable supply to the public (ibid.). The German Federal Office of Civil Protection and Disaster Assistance underlines the importance of the regional and local level at the interface between climate change and civil protection (BBK 2012a).

With reference to the German Adaptation Strategy, the German states (Länder) have been working on the topic of climate change and have developed regional adaptation strategies for many areas. “The long-term goal of the regional government (North Rhine-Westphalia, authors’ comment) [is, for example,] to reduce the susceptibility of people and the environment” (MUNLV 2009, p. 9). In its position paper on climate change, the Deutscher Städtetag (German Association of Cities) (2012) refers explicitly to the effects of climate change on individual cities. It examines climate change effects on different sectors such as building, traffic, health or water. The guideline links into this position paper by including a range of players such as environmental agencies, town planners, emergency services and electricity suppliers. This is also practical as much of the data and information needed for assessing vulnerability is stored at different places in the municipality and therefore, cooperation will be required in any case. Inter-authority cooperation is necessary for the successful development of measures e. g. in the field of early warning or urban development.

There are other processes besides climate change that influence the changing risks for the population and CIs. These include primarily the increasing dependency on the infrastructure services. For example, a report by the Office of Technology Assessment at the German Bundestag points out that a country-wide power failure lasting several days would be similar to a national disaster (cf. Petermann et al. 2010), as nearly all areas of our daily lives depend on the almost uninterrupted electricity supply. The electricity supply itself is currently facing major challenges brought about by restructuring processes towards a sustainable supply system based on renewable ener-

gies and the required “Smart Grid”. In this regard, cooperation between local authorities and operators is also necessary and may bring new challenges as well as opportunities.

Another inherent trend, although not the focus of this guideline, is demographic change. The declining population numbers and the increasing proportion of elderly people in some regions create new challenges for the infrastructure and civil protection.

Against this background, the relevant actors who should be involved in the analysis and reduction of vulnerability of the population and CIs are – in addition to the authorities and organisations involved in civil protection – primarily members of the public and private companies. This is particularly relevant when considering potential power failures. Businesses are affected by power failures on the one hand as suppliers but also as consumers. At the same time, as predominantly private suppliers, they take on important functions in communal life. If operators fail in their duties or disaster management systems break down, dramatic effects on the public may occur. This was demonstrated dramatically by the Tohoku earth-

quake in Japan in March 2011. The operator of the nuclear power plant complex which was destroyed by the tsunami had wrongly assessed the risk of a tsunami: the disaster management measures in place were inadequate and the government had to evacuate the inhabitants affected by radiation. Besides the issue of vulnerability of the CIs themselves, there is also the question of the potential impact on the population in case of a failure or damage and of the potential measures for reducing vulnerability towards such failures. This guideline therefore stresses the importance of cooperation between operators and municipal authorities at many points. A questionnaire in the form of a check list is included here as a starting point for assessing the vulnerability of municipalities towards electricity supply failures. This is important in order to develop practical disaster risk management measures. Since capabilities of the emergency services will however reach their limits during a longer-lasting power failure, it is necessary to check which tasks the population and the operators of critical infrastructures can implement by themselves and to what extent public assistance is necessary or possible.

2.3 Definitions, Terms and Concepts

2.3.1 The concept of vulnerability

A fundamental approach in the KIBEX project which is reflected in the structure of the guideline is that of *vulnerability*. There are various definitions and interpretations of vulnerability (see for example Füssel und Klein 2006, Thywissen 2006, Birkmann 2006, Parry et al. 2007 or UN/ISDR 2009,). Vulnerability to a natural hazard describes in general the sum of all factors and processes which define the extent of the possible damage and functional impairment caused by the natural hazard. These factors and processes can be reflected in various forms, such as the fragility of objects (e. g. CIs) or poor management and governance structures. It is therefore assumed that the consequences of a natural hazard do not depend only on its intensity or its spatial extent but are also determined significantly by the vulnerability.

The KIBEX project adheres to an understanding of vulnerability in which *exposure*, *susceptibility* and *coping capacity* represent the three components of the vulnerability of a system. *Exposure* captures the spatial and temporal aspect of “being subjected to” a natural hazard. *Susceptibility* and *coping capacity* describe the likelihood to suffer harm due to a natural hazard event (for example the absence of or inadequate building standards) and the availability of resources and capabilities to minimise the negative effects of natural hazards respectively (for example the presence of social networks and/or insurances) (cf. UNISDR 2009, Birkmann 2006).

Vulnerability can therefore be defined as a function of exposure, susceptibility and coping capacity:

Vulnerability analyses often consider the adaptive capacity of the system which is sometimes difficult to separate from the coping capacity. The question of the adaptive capacity of the two sectors investigated was not explored directly in this project; it rather focused on vulnerability and appropriate measures to reduce it. Adaptive capacity is distinguished from coping capacity particularly in terms of its time frame and therefore in the type of potential measures. While coping capacity tends to cover the short-term response to a natural hazard, adaptive capacity relates to long-term developments which usually involve a fundamental change (cf. Birkmann 2011). Adaptation of the supply networks and therefore a reduction in vulnerability of the electricity supply to natural hazards can involve the adaptation or restructuring of the grid. As described in Chapters 4 and 5, short-term coping measures, in contrast, relate to such things as the level of preparation of the supplier and their options for replacing components if necessary or establishing emergency connections. In this case the measures involved aim at minimizing the negative effects of the natural hazard event. Long-term technical adaptation measures such as the modification of the supply grid which extend beyond the municipal level are not discussed in any greater detail in this guideline.

On the other hand, there is no distinct division line between coping capacity and adaption for the population sector. Important measures which contribute to increasing coping capacity for heat waves and heavy rainfall events consist of structural modifica-

$$\text{Vulnerability} = f (\text{Exposure} \times \text{Suscpetibility} \times \text{Coping capacity})$$

tions like insulation and backflow prevention devices as well as financial capacities such as insurances, which may well be seen as adaptation measures to climate change. In this sense the adaptive capacity would specifically include resources which enable

implementation of these precautions. However, awareness/risk assessment and the available knowledge about potential measures have a major influence on whether the existing resources for adaptation measures are actually used.

2.3.2 Critical infrastructures

The vulnerability concept can in principle be applied to various areas such as environmental, economic and social systems (cf. Birkmann 2006). This guideline focuses on the direct effects on the population from the stated natural hazards and the indirect consequences from the possible failure of critical infrastructure services. According to the German Federal Ministry of the Interior (BMI), the latter comprise

„organizational and physical structures and facilities of such vital importance to a nation's society and economy that their failure or degradation would result in sustained supply shortages, significant disruption of public safety and security, or other dramatic consequences”

(BMI 2009).

Critical Infrastructures can be divided into basic technical infrastructures and socio-economic service infrastructures, as shown in Table 1. The guideline focuses on the one hand on the electricity supply as a basic infrastructure which is also essential for the operation of many other infrastructures. On the other hand it examines those service infrastructures which support a large number of vulnerable people who may not be able to look after themselves and who therefore represent vulnerability *hot spots*. These include e. g. nurseries, hospitals, old people's homes and nursing homes and facilities catering for people with disabilities. These are not mentioned specifically at a federal level. However, as the criticality of infrastructures (cf. Fekete 2011) is dependent on the spatial level under consideration, they are examined in this guideline under the socio-economic service infrastructures.

Table 1: Definition of critical infrastructures

<u>Basic technical infrastructures:</u>	<u>Socio-economic service infrastructures:</u>
Power	Transport und Verkehr
Information technology and telecommunications	Finance and insurance
Health	Government and administration
Water	Media and culture
Food	Nurseries, hospitals, old people's homes and nursing homes and homes for the handicapped

Source: own presentation based on BMI, 2009, p. 8 and BSI and BBK 2013.

Overall, the importance of the critical infrastructures has grown significantly in recent years. This is partly due to the events of September 11th 2001 and to the summer flood event in Germany in 2002 which revealed the vulnerability of infrastructures demonstrated by the major damages resulting from the event. Moreover, critical infrastructures are subject to major changes e. g. in the context of mitigation efforts which shape their vulnerability (see also chapter 2.2) and thus have risen in public awareness.

With respect to electricity supply, additional factors such as the ongoing European networking and interlinking of systems and an increasing number of players due to privatisation and the deregulation of the European market shape the system complexity (cf. IRGC 2006, Kröger 2008) providing new challenges for the grid management. At the same time, these developments mean that failures can have wide-ranging consequences. This was the case in November 2006, when a high-voltage cable was erroneously switched off and led to a power cut throughout Europe which affected approx. 10 million people in Germany, France, Italy, Belgium, Spain and Portugal (UCTE 2007).

Besides the vulnerability of the infrastructure as such, the *growing dependency* of people and the processes and sectors of society on the electricity supply needs to be considered. This has a decisive impact on the effects of a power failure. Due to the very high security of supply⁵, members of the public do not expect a major failure and it can be assumed that preparations for the resulting emergency situations are inadequate.

“The more a country’s susceptibility to failures as regards supply services decreases, the more severe will be the impact of an actual disruptive incident.”

(BMI 2009, p. 10).

This is not only relevant for the supplier or the country, but also and in particular the municipalities which have to respond to this (cf. BBK 2010). In response to these circumstances, a qualitative evaluation of the effects of a power failure on the municipal districts was generated (see Chapter 6).

⁵ In 2011 the length of interruptions was ca. 15 min/year (Bundesnetzagentur 2012).

2.4 The use of indicators and criteria

In order to transfer the concept of vulnerability into something which could be applied to the population and CIs and to allow for the assessment of quantitative and qualitative differences in vulnerability factors, relevant aspects were translated into *indicators* or *criteria*. They differ in terms of their measurability and data availability. Indicators are based on measurable values and mostly relate to data which is generally available in local authority statistics. Indicators allow susceptibility and coping capacity factors to be assessed without these being measured directly. Indicators are therefore substitute variables. For example the indicator *percentage of the population living alone and aged 65 years and older* represents an important factor for the susceptibility of the population. This percentage can indicate a high or low susceptibility, depending on its value. A spatially differentiated representation of the indicator is generated using the administrative units for which the data was recorded. City districts can therefore be compared with each other and appropriate action can be developed.

In terms of the definitions in this guideline, criteria are less quantitatively measurable but describe qualitatively defined relationships which affect vulnerability. There is generally no data available in the

municipal statistics for criteria at the small-scale level (e. g. city district level). However, they describe important factors which affect vulnerability and should therefore be included in the analyses as part of a detailed examination. Examples include the existence of backflow flaps in houses or the availability of a natural hazard insurance (both from the coping capacity sector). These factors which influence vulnerability play an important part in the development of appropriate practical measures (e. g. suitable information flyers for the public). The relevant data can sometimes be generated by means of household surveys and thus be made available at the desired administrative level.

Both indicators and criteria are used in the guideline in order to describe the direct impacts of natural hazards on the two areas population and CIs. In contrast, the indirect consequences of potential failures in infrastructure services and the vulnerability of municipalities to power cuts are represented purely by criteria as they do not lend themselves to quantitative measurement. Both, indicators and criteria, provide valuable information for local authorities in order to develop civil protection measures and to target particularly vulnerable groups and sectors.

2.5 Changes in extreme weather events

The guideline presents methods for assessing the vulnerability of the population and CIs to heat waves and heavy precipitation events⁶. This involves extreme weather events which can impact on municipalities to differing degrees within their overall area. This angle is looked at for each natural hazard under the aspect of exposure. For example, caused by the urban heat island effect (UHI) in the highly sealed inner cities it can be considerably warmer than in outlying districts (Bornstein 1968, Aniello et al. 1995, Golden 2004). However, under the influence of climate change it can also be assumed that the intensity and frequency of extreme events is changing (see chapter 2.2). While the final report⁷ uses projections from different climate models for analysing potential

future climatic conditions, only past changes in extreme weather events are used at this point. For example, looking at the two municipalities of Karlsruhe and Wuppertal, the changes which could be established in heat wave days⁸ and heavy precipitation events are presented. Figure 1 shows how the frequency of heat wave days has changed over the period from 1876 to 2008 at the Karlsruhe-Hertzstrasse weather station. There has been a highly significant increase of 0.1 days per year over the observation period. While the average annual number of heat wave days was around 6 in the period from 1961-1990, it amounted to almost 18 heat wave days per year in the period from 1999-2008.

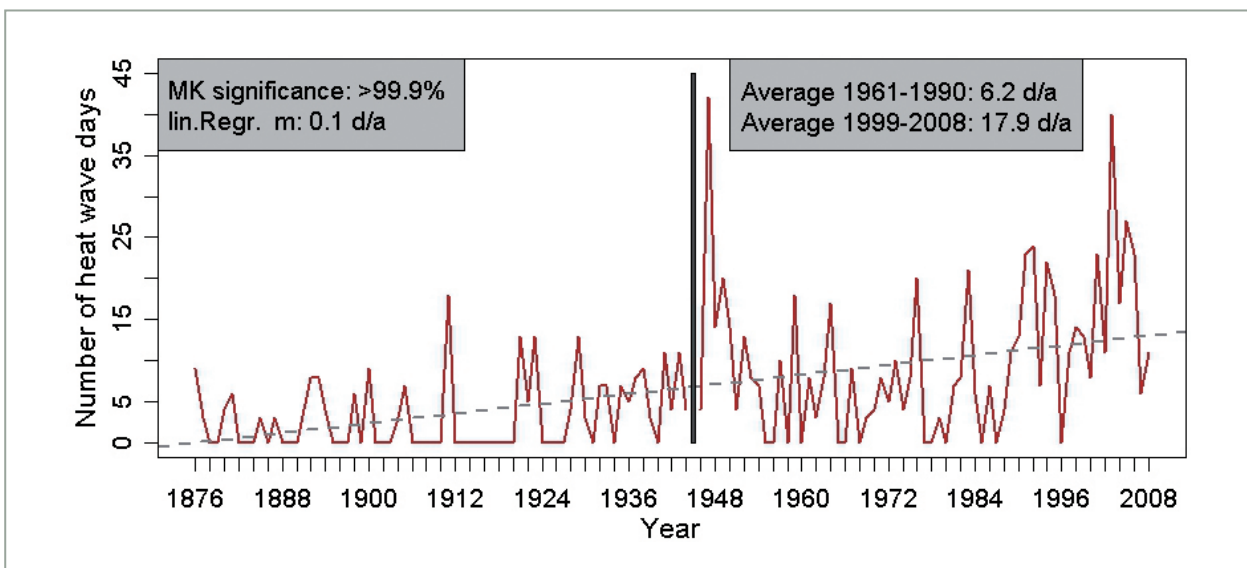


Figure 1: Annual number of heat wave days based on observations of climate data at the Karlsruhe-Hertzstrasse station. The figure also shows the linear regression line (dotted), its gradient, the significance values from the Mann-Kendall trend test (top left) and the average number of heat wave days per year over the periods 1961-1990 and 1999-2008 (top right). The black bar marks the missing value for 1945.

Source: own figure based on WebWerdis data.

⁶ It must be noted that the presented method in chapter 5 for assessing the vulnerability explicitly refers to heavy rainfall events. In this context here, heavy precipitation can also include hail and snowfall.

⁷ Additional information is available in the final report which will be published in the "Forschung im Bevölkerungsschutz" series of the BBK.

⁸ A heat wave day is determined as one out of at least three days in a series of a maximum temperature of at least 30°C (Lissner et al. 2012).

A similar analysis was carried out for the occurrence of heavy precipitation events in Wuppertal (see Figure 2). Results for the Wuppertal-Buchenhofen station which lies closest to the city centre show a slightly significant trend for the annual change in the occurrence of daily heavy precipitation (≥ 20 mm per day) for the period 1951 to 2008. While the annual num-

ber of heavy precipitation days between 1961-1990 was 6 days, from 2001 to 2010 it was over 8⁹. These analyses refer to specific weather stations. However, comparable developments can be anticipated in the future for particular regions in Germany, depending on the natural geographic region (cf. Zebisch 2005 or Rannow et al. 2010).

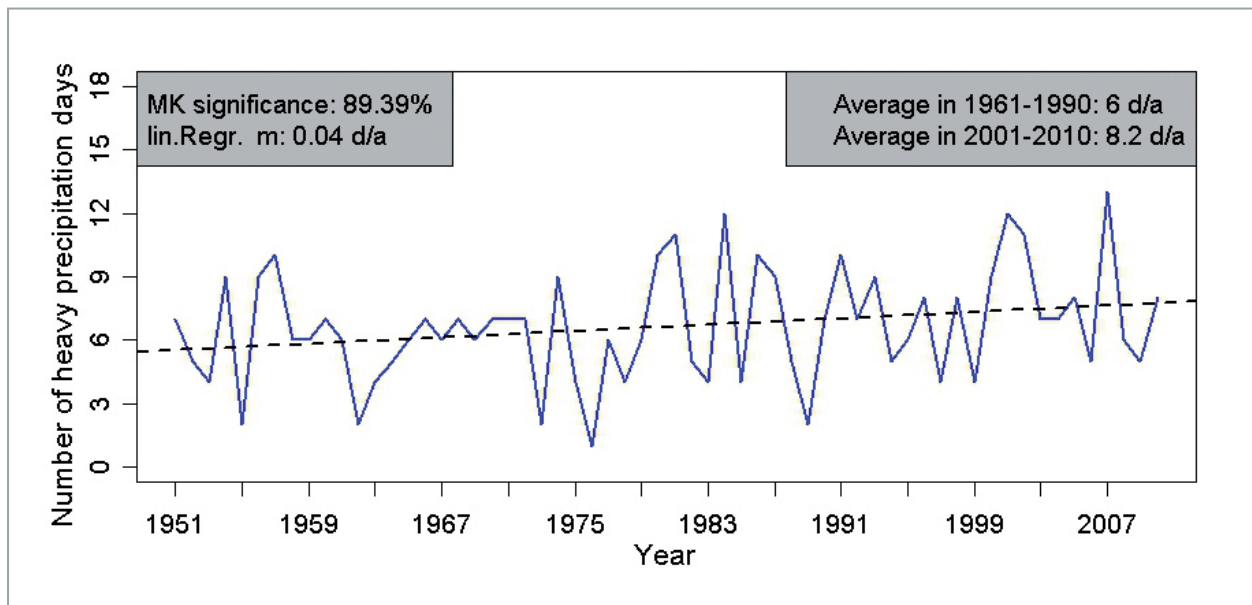


Figure 2: Annual number of heavy precipitation days based on observations of climate data at the Wuppertal-Buchenhofen station

The figure also shows the linear regression line (dotted), its increase, the significance values from the Mann-Kendall trend test (top left) and the average number of heavy precipitation days per year over the periods 1961-1990 and 2001-2010 (top right).

Source: own figure based on WebWerdis data.

⁹ It must be noted that these figures refer to daily values because data of a higher temporal resolution was not available for the whole of the time period under analysis. However, heavy rainfall events are characterised by high amounts of precipitation which fall within a short unit of time (e. g. an hour) (cf. DWD 2010).

2.6 Application of the guideline and user groups

The guideline is aimed specifically at local authorities who have to address new challenges at local level due to climate change, also with respect to civil protection. As this can only succeed in cooperation with the emergency services and operators of CIs on the ground, the guideline has two basic aims. The first is the assessment of vulnerability to heat waves and heavy rainfall for the population and critical infrastructure sectors as well as the vulnerability assessment of municipalities to power failures. However, as effective strategies for reducing vulnerability can only be developed using concerted and coherent measures, the implementation should also aim for improved cooperation within the municipality. This will come about firstly through the necessary data and information which may need to be exchanged between the various parties. However, implementing the measures will also require cooperation within the municipality, for example between the municipal sewerage operator and the fire brigade in relation to reducing vulnerability to heavy rainfall events. On the one hand close cooperation between the different players in assessing vulnerability improves the quality of the results and increases acceptance of the measures developed. On the other hand, determining vulnerability leads to a basic added benefit in the communication between the institutions and authorities. Synergies can often be created or existing knowledge and measures whose potential would remain unused without an exchange between the different agencies can be transferred. The analysis of local vulnerability should therefore include the setting up of interdisciplinary discussion platforms where possible.

In order to carry out a comprehensive analysis for the municipality, it is best to use the whole guideline, following the individual chapters. Depending on which natural hazard(s) is/are of relevance for the

municipality and on which measures have already been taken, the assessment may however make use of individual sections only.

For some areas the guideline presents different options for undertaking the assessment. This should allow for the specific capacities and needs of the municipalities. The various methods mostly differ in terms of the amount of work and costs. In some areas, such as the assessment of exposure to heat waves, reference has been made to the high variability in data availability and capacities in the individual municipalities.

The benefit of a vulnerability assessment (which is also required by the Länder and federal governments¹⁰) is initially to be found in an improvement in the protection of the public and therefore the safety of the municipality. At the same time such assessments also form a recognised means of adaptation to climate change (cf. Bundesregierung 2008). All in all, the assessment can result in the creation of synergies and achieve saving effects by transferring existing measures. The innovative development of measures can also generate additional resources. For example, by taking part in competitions such as the innovation prize for fire brigades (IF Star 2012) or the Blue Compass 2011 which is awarded by the German Federal Environment Ministry and the German Federal Environment Agency (UBA), the partner city of Wuppertal was able to obtain funds which are now channelled into implementing various measures. Aside from this, it was ensured that different methods were developed which were as cost-effective as possible. If technical options exist for obtaining more accurate results, these are presented and explained as alternatives. The local authority can select a suitable method depending on their budget and the level of detail required.

¹⁰ Cf. Bundesregierung 2008, p. 4 or MUNLV 2009 p.155.

2.7 Structure of the guideline

This publication presents options for assessing the vulnerability of the population and CIs to heat waves and heavy rainfall using the concept of vulnerability based on the three sub-categories *exposure*, *susceptibility* and *coping capacity*. The methods are presented separately for the natural hazards heat waves (Chapter 4) and heavy rainfall (Chapter 5). The analysis can be restricted to one natural hazard only,

depending on the relevance of the natural hazards to the municipality, although potentially climate induced changes should be taken into account. The two chapters are sub-divided into the fields *population* and *CIs*. The vulnerability aspects exposure, susceptibility and coping capacity are explained for both natural hazards and the respective fields under consideration.

Overview for use of the guideline by the municipalities:

While Chapters 2 and 3 outline the framework of the guideline and describe the concept and the target group in more detail, Chapters 4 to 6 present the methods developed for assessing vulnerability which should be put into practice by the municipalities.

Chapter 4 deals with the assessment of vulnerability to heat waves and is sub-divided into methods to assess the urban heat island effect (4.1), vulnerability of the population to heat waves (4.2) and vulnerability of critical infrastructures to heat waves (4.3).

Chapter 5 is divided into the same areas for analysis. For the natural hazard heavy rainfall, the method for identifying depressions (5.1) is first explained, followed by the vulnerability of the population (5.2) and critical infrastructures (5.3).

Finally, Chapter 6 discusses the assessment of the vulnerability of municipalities to power failures and appropriate action strategies.

III. Chapter

Assessment methodology

3.1 Analysing vulnerability to heat waves and heavy rainfall

The conceptual framework of vulnerability can be applied to various extreme weather events, although their effects on the population and CIs differ. These effects are dependent on the type of natural hazard which can occur either *slowly* or *suddenly*. Heavy rainfall as a *sudden-onset* natural hazard characterised e. g. by being accompanied by great physical powers of destruction, particularly on steep slopes. It is limited in space and time (Gaume et al. 2004).

In contrast, the *slow-onset* hazard heat wave is much more far-reaching in its temporal and spatial extent and, in addition to direct effects e. g. when it causes heat stroke, often has indirect effects (McGregor et al. 2005). The public is not usually affected by the destruction of property as may be the case with heavy rainfall. Infrastructure components are not physically destroyed but limited in their operational capability. For instance, problems may arise for electricity generation due to the shutdown of power plants to avoid a further increase in water temperatures in rivers and the accompanying damage to ecosystems (see e. g. Rothstein et al. 2008). The limited generation may be accompanied by an increased consumption (e. g. use of air conditioning) which can lead to an imbalance in the supply and demand and therefore to supply

bottlenecks (see e. g. BAG 2003, BfG 2006, Lönker 2003 or Bundesregierung 2008). There is usually a difference in the direct and indirect effects of natural hazards, so that suitably differing methods have been developed to assess vulnerability, as shown in Figure 3.

The assessment of the *exposure* component of vulnerability in particular varies depending on the natural hazard. There is no clear spatial edge of a heat wave (e. g. in comparison to a flood), however small-scale differences in exposure can be determined due to the urban heat island effect (UHI). In the case of heavy rainfall, the topographical depressions in the municipality are a feature of great importance because water may collect there and lead to local flooding. A second step is then necessary to check the degree to which people and facilities or supply components are *exposed*, i. e. physically at risk from the specific hazard. This is generally done by intersecting the results of the UHI or the topographical depressions with population data or geographical data on public facilities or supply components which is held by the local utility companies, the fire brigade or the local government statistical office, real estate office or land register.

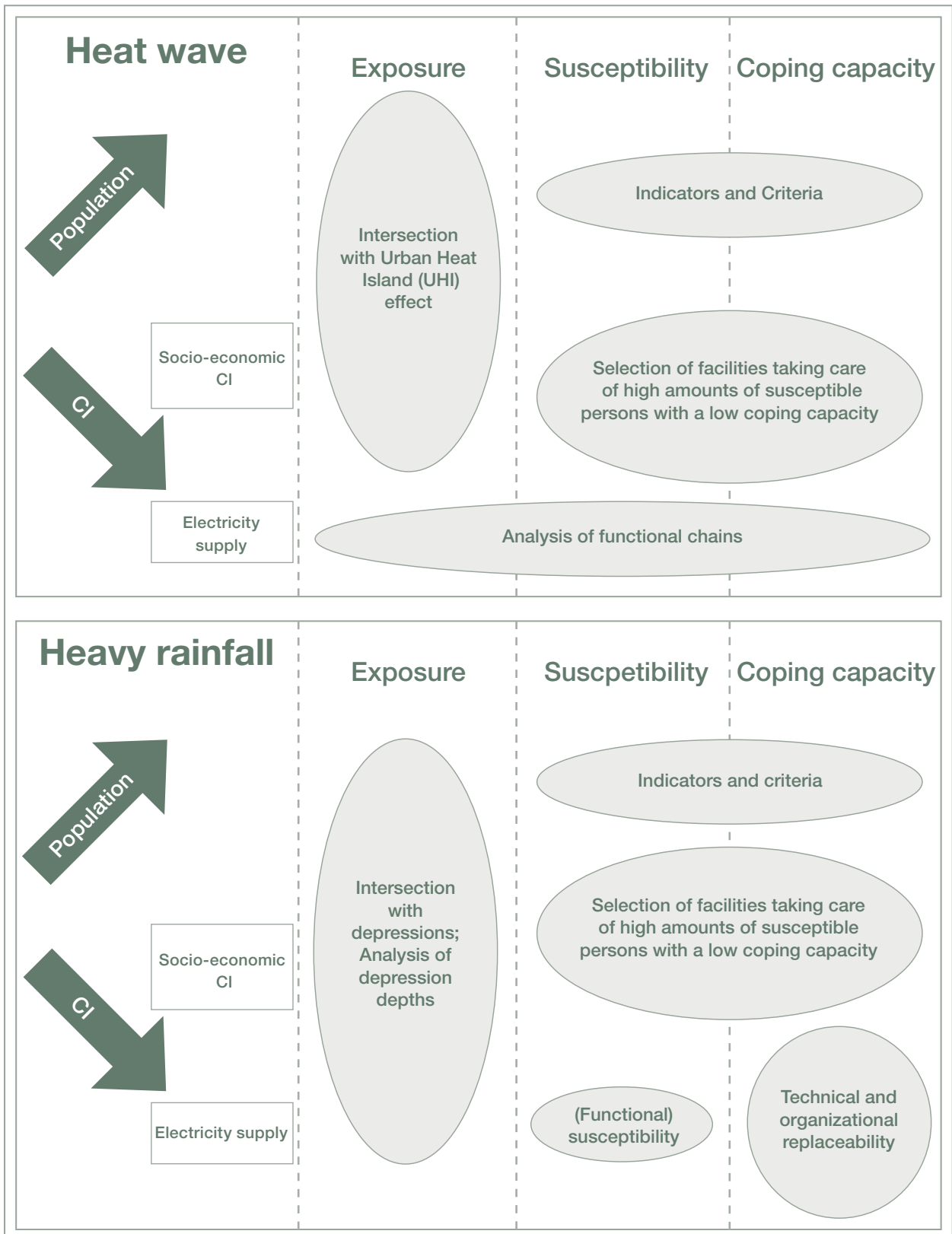


Figure 3: Overview of methods for analysing the vulnerability of the population and CIs to heat waves and heavy rainfall¹¹

Source: own figure.

¹¹ The electricity supply was selected to illustrate the basic infrastructure. As it forms the basis for other infrastructures, its failure will have farreaching consequences.

3.2 Two-stage process for assessing vulnerability

A two-stage process was developed for using the guideline and carrying out the municipal vulnerability assessment for heat waves and heavy rainfall which enables examination of the two areas of *population* and *critical infrastructures* and integrates the analysis of the effects of a (partial) failure of the electricity supply on the municipality.

First, a *direct* assessment of the vulnerability of CIs and the population is carried out for each of the natural hazards (both heat waves and heavy rainfall) (see Figure 4).

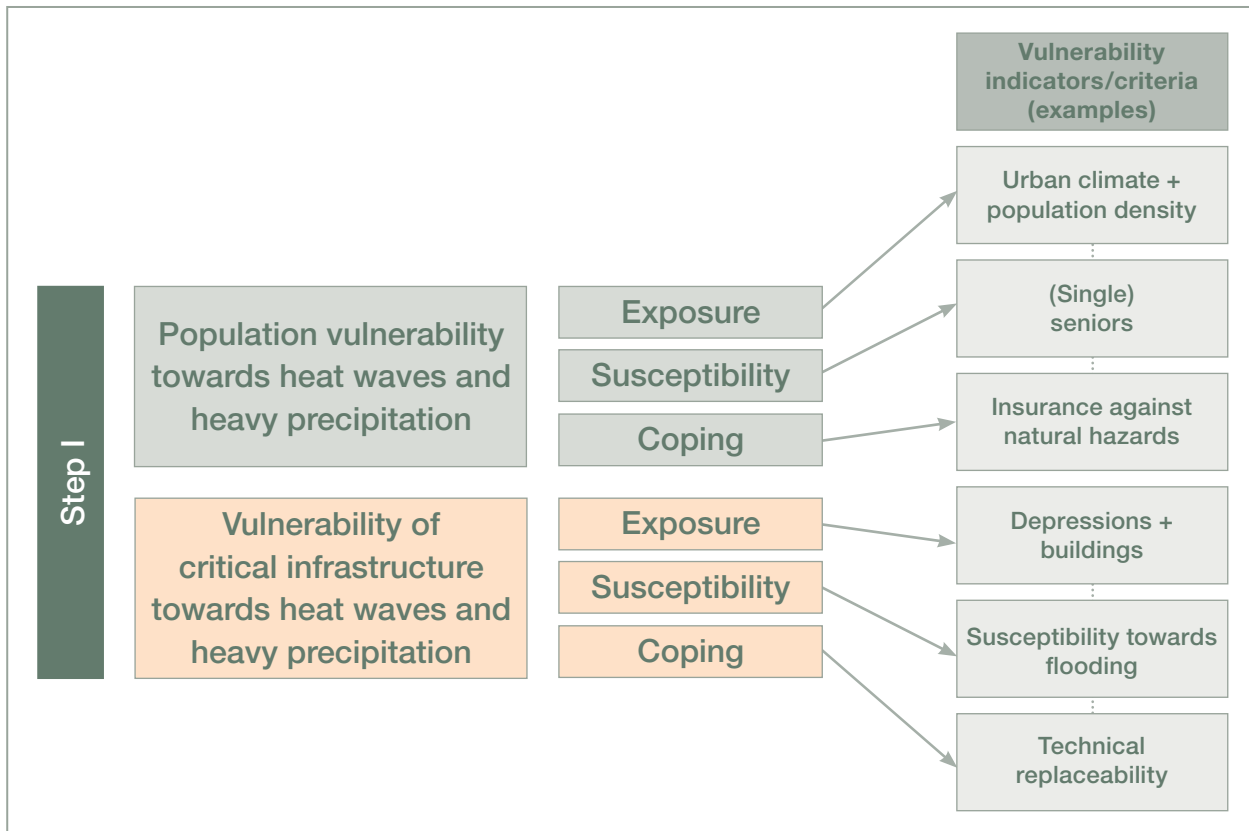


Figure 4: Assessment of direct vulnerability of population and CIs

Source: own figure.

In order to take account of interactions between the two fields, a second step is then required to analyse the *indirect* effects of the natural hazards. The guideline focuses on the issue of how the failure of

an infrastructure service – the electricity supply in this case – would impact on the municipality and the emergency services in particular (see Figure 5).

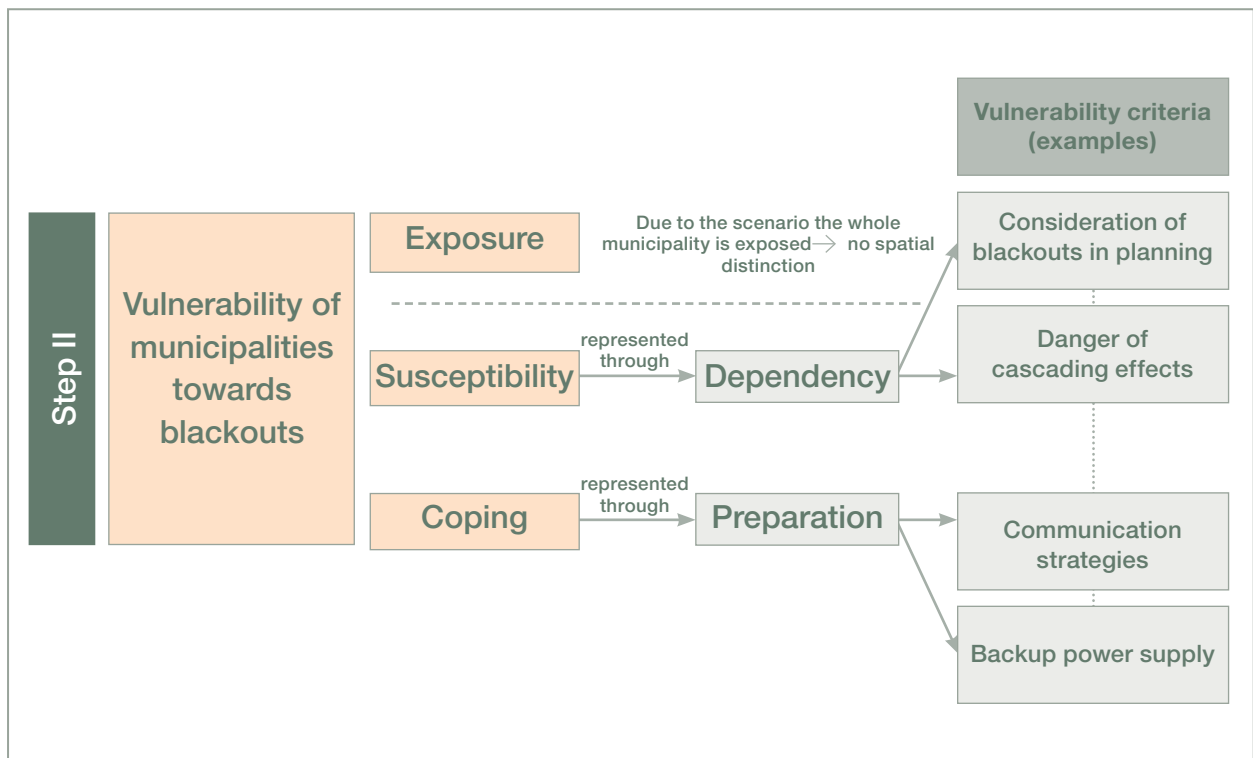


Figure 5: Assessment of the indirect vulnerability of a municipality exemplified by electricity failure

Source: own figure.

The assessment of the indirect vulnerability of the municipality to possible failures/impairment of infrastructure services using the electricity supply as an example is carried out in the form of check lists (see Chapter 6) in order to ascertain the varying dependency (susceptibility) and the level of readiness of

the emergency services, population and businesses. The checklist is intended as aid for the municipalities. With its help, possible problems can be anticipated and appropriate measures can be developed, discussed and if necessary practiced.

IV. Chapter

Vulnerability assessment of the population and
critical infrastructures to heat waves

4.1 Methods for assessing the urban heat island effect

A heat wave is a prolonged period with unusually high temperatures but different definitions exist for determining its frequency and duration. Relative indices offer the possibility to consider regional climatic conditions and the acclimatisation of people to them. However, we use the absolute index *heat wave day* (see Lissner et al. 2012), which refers to a maximum temperature over 30 °C on three consecutive days. In principle it is also possible to use other indices for the definition or analysis of heat waves such as the number of hot nights (minimum temperature above 20 °C) (see also Alexander et al. 2006). The latter are of particular importance when considering the effects of heat waves on health because they take away the possibility for people to recover from a hot day during the cool night. More complex definitions include relative humidity as well as taking account of the greater stress of high temperatures combined with high humidity¹².

The exposure to heat waves is especially variable in urban areas, with city centres generally being particularly affected (urban heat island effect, UHI). In order to take account of this variable level of impact on the municipality, an assessment of the UHI has to

be carried out for which various methods are suggested below.

Heat stress can likewise vary in rural areas due to biogeographical heterogeneity. However, this is less important as a cause of temperature differences within a municipality.

There are different options for assessing the UHI. The methods

- a) Assessment using weather station data,
- b) Assessment using remote sensing and
- c) Assessment using urban climate models

are presented in what follows. These differ in terms of the data on which they are based, the amount of work involved, the necessary knowledge and resources and their precision (see Table 2). They are explained individually so that the municipalities can undertake their own assessments in line with their resources and requirements.

¹² In the literature this indicator is also referred to as *apparent temperature* (Steadman 1984).

Table 2: Differences in the various methods for assessing urban heat island effects

	Weather station data	Remote sensing data	Urban climate models
Data required	Weather station data (e. g. DWD data); independent variables required for statistical processing (e. g. height).	High resolution thermal remote sensing data from flights or satellite data; although MODIS data are freely available they have a very low resolution of approx. 1 km x 1 km which may be too coarse for a survey at municipal level.	Urban climate model
Processing effort	Statistical and geocoded data processing; moderate processing effort.	Statistical and geocoded data processing; moderate processing effort.	Simple mathematical calculations based on geographical data on the urban climate; low processing effort.
Costs	Simple data acquisition, relatively low costs.	High, if flights first have to be conducted; if using the free MODIS data: very coarse resolution.	Low: it is assumed that an urban climate model exists.
Required knowledge	Knowledge of climate data processing; of geocoding weather station data and municipal maps; of applying the regression and interpolation procedures; of geostatistics.	Knowledge about processing the satellite data; handling remote sensing data and geographical data; geocoding.	Knowledge on assessing the urban climate model results incl. summarising into an urban climate map.
Accuracy level	Spatial resolution up to 100 m x 100 m; good temporal resolution of the data; population density can show deviations from actual values as it is disaggregated municipal level data (Gallego, 2010).	Spatial resolution of satellite data of 1 km x 1 km; higher resolution possible with survey flights (but linked to high costs); temporal availability of data is limited; only surface temperature available.	Data mostly based on measures and modelling; the level of precision is therefore high.

Source: own figure.

It must be borne in mind that the methods described should enable an *assessment* of the potential heat island effect in the municipality¹³. Assessments using weather station or remote sensing data in particular permit an immediate and cost-effective assessment. However, in principle all methods which aggregate the data to the level of a city district (or higher) lead to a simplified presentation and therefore a bias. This effect is reduced by having a presentation with as high a resolution as possible, e. g. at housing block level. The methods shown here were used at the city district level and are therefore only an *approximation* of reality¹⁴.

The municipality can select the methods based on the resources available and the desired level of precision. Mapping to as accurate a level as possible can also be achieved by using e. g. surveys, wind tunnel studies or simulation models (cf. e. g. NVK 2011) but is accompanied by a corresponding cost. Irrespective of which method for assessing the UHI the local authority decides on, this forms the basis for the further examination of *exposure* of the population and CIs (cf. Sections 4.2 and 4.3).

4.1.1 Assessment based on weather station data

To assess the exposure of the population, the temperature distribution has to be known with as high a degree of spatial resolution as possible, as it is influenced by a range of factors and can therefore vary markedly over the area of the city. Using this method to assess the UHI in a city, weather station data from the surrounding area, in our example from the city of Karlsruhe, is used. A combination of regression and interpolation methods allows to raise the generally very low resolution (the distances between available weather stations usually constitute dozens of kilometres) up to a higher resolution of the explaining variables (e. g. population density).

Although other climatic factors such as wind speed, duration of sunshine, radiant power, humidity etc. can be of importance for the current heat stress of the human body (e. g. Kjellstrom 2009), only the climate factor of temperature is used here. Easily accessible WebWerdis data¹⁵ are used for this. The weather data from the stations are then aggregated into the above-mentioned heat indices, where the heat wave day was selected for the example of Karlsruhe. In this case the maximum daily temperatures of the stations in the vicinity of the sample city Karlsruhe are used.

¹³ Further comments on this can be found in the scientific final report in the series "Forschung im Bevölkerungsschutz" which will be published by the BBK.

¹⁴ For Karlsruhe, for example, the existing climate function map provides a view of the urban climate which is substantially accurate in all details and therefore more precise. However, respective maps exist only in a minority of German municipalities which is why the other methods are also described (using the City of Karlsruhe as an example).

¹⁵ DWD data platform: <http://www.dwd.de/webwerdis>.

The basic idea now is to explain the measured heat waves at the individual stations with the influencing factors which surround them. High resolution data (100 m x 100 m) e. g. for topography and population density are used for this. This data is mostly publicly available (see above WebWerdis data or CORINE data at <http://www.eea.europa.eu/>). The topography can be used to describe the temperature distribution in a region due to the physical relationship between height and temperature of an air mass. The population density on the other hand serves as a proxy (substitute variable) for various factors affecting temperature,

such as the quantity of buildings which store heat, or anthropogenic heat emissions, percentage of sealed ground, etc. (see UHI above). The influencing factors around a station are recorded using what are known as *buffers*, i. e. areas of influence of a specified size. By way of example we have chosen a radius of 2,500 m here. Applying the parameters found using the linear regression to the average height and the population density in the city districts gives information about the district specific UHI. Both, the height and the population density are used as independent variables to describe the UHI (see Figure 6).

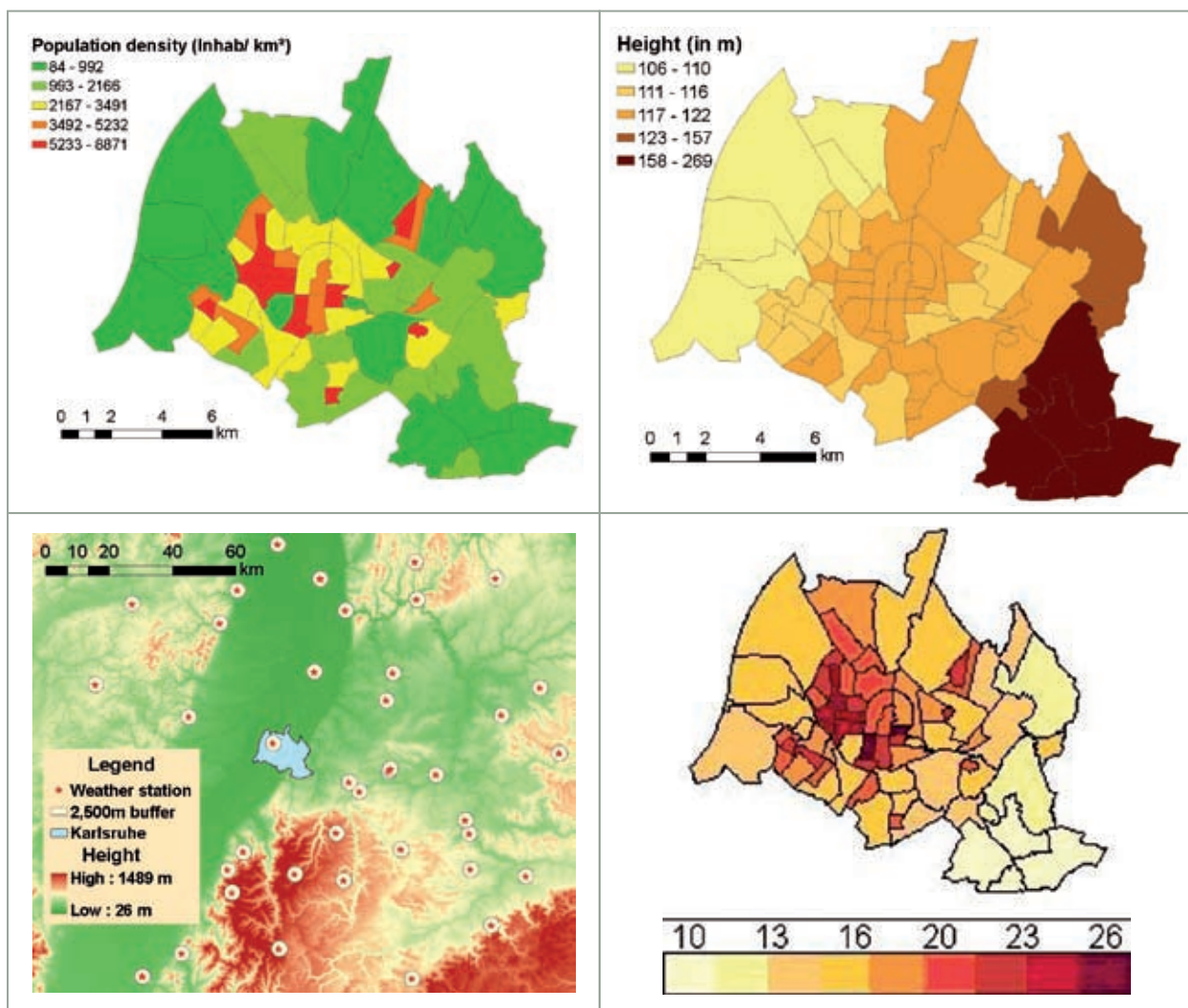


Figure 6: Height, population density and heat indices in Karlsruhe

The independent variable "height" around Karlsruhe is shown at the lower left. Sample stations with buffers of 2,500 m diameter are also shown. In the top left and top right are the values of the independent variables population density and height for the city districts in Karlsruhe. The heat indices for each city district calculated using height and population density are shown at the bottom right.

Source: own figure based on WebWerdis and CORINE data.

4.1.2 Assessment using remote sensing data

A further option for assessing exposure to heat within the city is the use of satellite data. These are often publicly available, but do take time and expertise to process. In this example free MODIS land surface temperature (LST) data has been used with a spatial resolution of approx. 1 km. The temporal resolution of the data is specified by the time when the satellite flies over the region in question. In this case this always takes place at 10.30 hrs local time. Due to gaps in the data resulting e. g. from cloud cover, data is only available at an 8-day averaged resolution. As an

example, the data for June were averaged for the years 2006-2011. Figure 7 shows the mean surface temperature and the city districts of Karlsruhe. A clear relationship can be seen between increased surface temperature (red) and more densely populated parts of Karlsruhe and the surrounding area. There is a measurably higher surface temperature in these regions due to the factors described above such as anthropogenic heat emissions, heat accumulating materials and lower emissions of moisture due to sealed ground and less vegetation.

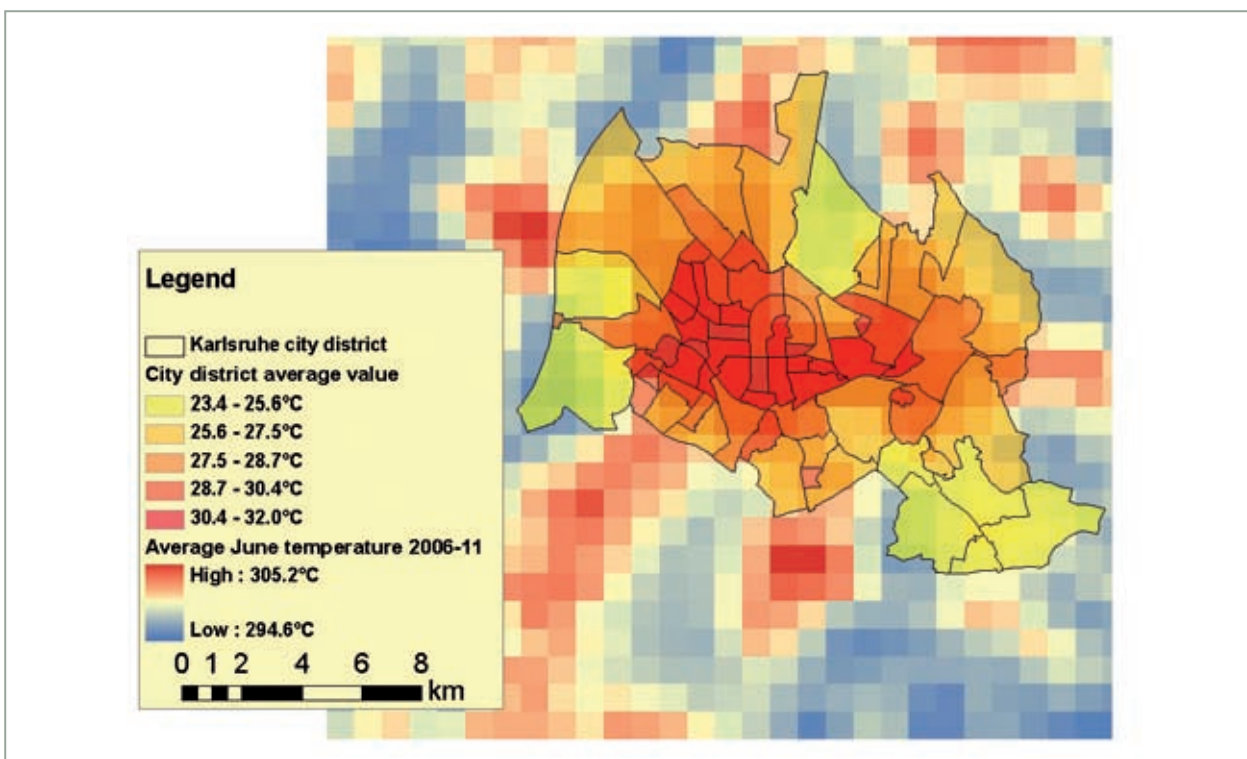


Figure 7: Average surface temperature in June in the Karlsruhe region
The averages of this variable across the districts of Karlsruhe are also shown.
Source: own figure, based on MODIS data.

4.1.3 Assessment based on urban climate models

The method for the UHI assessment based on urban climate models assumes that the local authority has already carried out a detailed study of the local climate in the past and that relevant maps, preferably in digital form, are available. As the urban climate is usually recorded independently of administrative units, the relevant information is aggregated at city district level. This enables an intersection with statistical data which are available in the relevant administrative units and thus allows for the assessment of vulnerability.

2011) which deals in particular with climate and air quality, so that different areas of the city could be assigned to a) pollution and heat stress zones and b) areas with compensating effects (see Table 3). Pollution and heat stress zones and areas with compensating effects can themselves be divided according to the criteria air pollution and thermal effects (NVK 2011). The two categories (air pollution and thermal effects) could be intersected both for the pollution and stress zones and also for the areas with compensating effects, as shown in Tables 4 and 5.

The method which has been developed is based on the local climate model for the City of Karlsruhe (NVK

Table 3: Classification of areas within the City of Karlsruhe in terms of climatic/pollution effects

Area function	Air pollution/thermal stress
Pollution and heat stress areas	Areas with increased air pollution
	Areas of thermal stress
Areas with compensating effects	Areas with cold air production/ cold air supply capacity
	Areas for air exchange

Source: own figure.

Table 4: Evaluation classes for pollution and heat stress zones in the City of Karlsruhe

	Pollution and heat stress areas	
<u>Stress due to heat/bio-climate</u>	<u>Increased stress due to air pollution</u>	
	Yes	No
Very high (4)	Very high (5)	High (4)
High (3)	High (4)	Moderate (3)
Moderate (2)	Moderate (3)	Low (2)
Low (1)	Low (2)	Very low (1)

Source: own figure.

Table 5: Evaluation classes for zones with compensating effects in the City of Karlsruhe

	Areas with compensating effects	
<u>Ability to derive fresh air</u>	<u>Part of a fresh air corridor</u>	
	Yes	No
Very high (4)	Very high (5)	High (4)
High (3)	High (4)	Moderate (3)
Moderate (2)	Moderate (3)	Low (2)
Low (1)	Low (2)	Very low (1)

Source: own figure.

The values of the categories "Areas with compensating effects" and "Pollution and heat stress areas" are then summarised in an overall matrix. In order to

present the urban climate at a city district level based on compensating and stress areas, the two values are linked using the following formula:

$$\frac{\text{Proportion of areas with air pollution} * \text{weighted average value of pollution and heat stress zones}}{\text{Proportion of areas with the ability to produce cold air} * \text{weighted average value of zones with compensating function}}$$

As the values compensating effect and pollution and heat stress can each have 5 levels, this results in 25

intersection values, as shown in Table 6.

Table 6: Classification of values from stress zones and zones with compensating effects

Compensation						
5	0,2	0,4	0,6	0,8	1	
4	0,25	0,5	0,75	1	1,25	
3	0,33	0,66	1	1,33	1,66	
2	0,5	1	1,5	2	2,5	
1	1	2	3	4	5	
	1	2	3	4	5	Stress

Source: own figure.

In order to divide the values into 5 urban climate index classes (green to red), an average urban climate was assumed where the value of the areas with compensating functions roughly corresponds to the value of the areas under pollution and heat stress and assumes a value of approximately one (shown in yellow). If the proportion of compensating areas (values < 0.8) predominates, then the urban climate index is shown as *compensated* (green); if the values

of the stressed areas (values > 1.25) predominate, then the overall climate is under greater stress and is shown in orange or red.

In order to assign the values as equally as possible within the two groups (favourable urban climate shown in green and unfavourable climate shown in orange/red) the classification has been chosen as shown in Table 7:

Table 7: Allocation of the intersected values of compensating function and stressed area for the urban climate index

Index value	Assignment of classes from spacial analysis
1	< 0,4
2	≥ 0,4 < 0,8
3	≥ 0,8 ≤ 1,25
4	> 1,25 < 2,5
5	≥ 2,5

Source: own figure.

If this index is shown at a city district level (see Figure 8) differences in the urban climate are easily visible for the City of Karlsruhe.

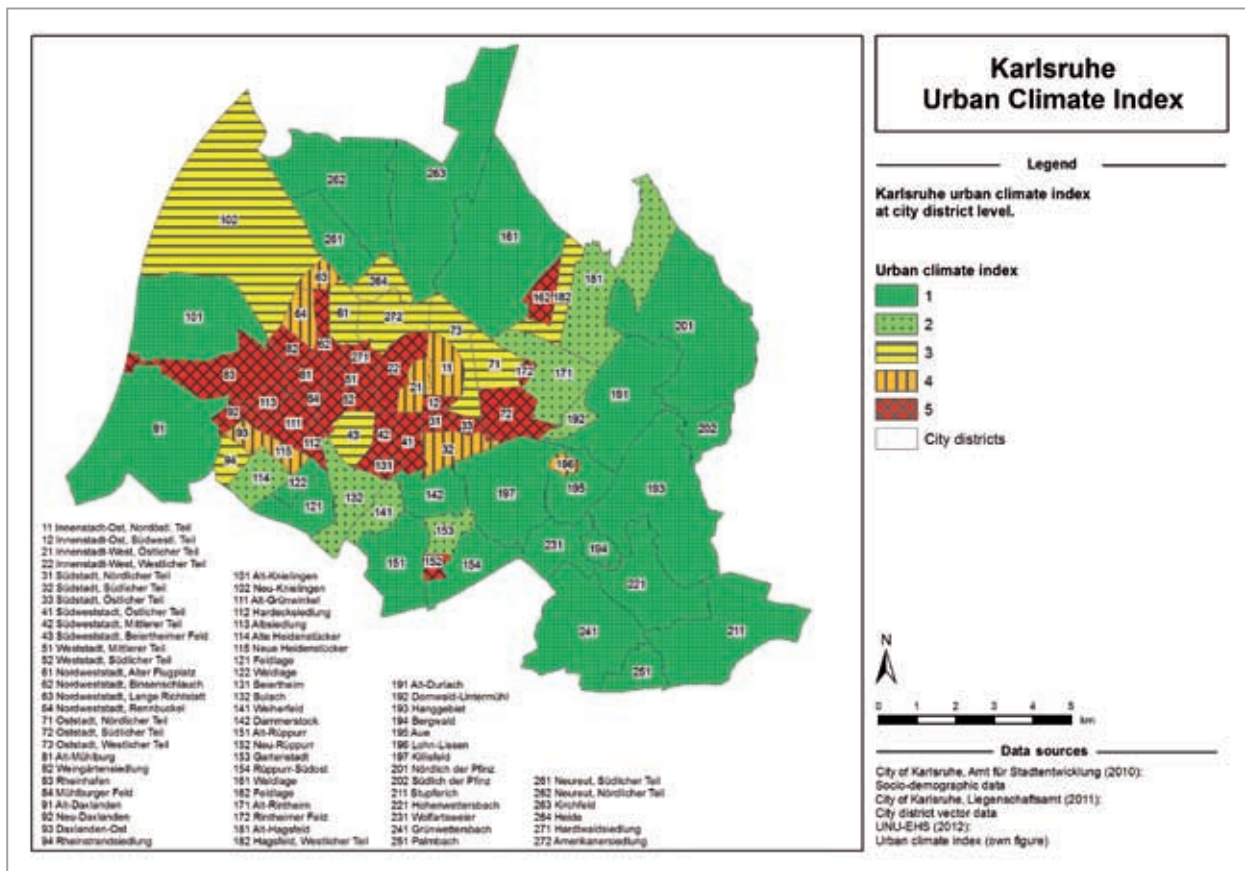


Figure 8: Cartographic view of the urban climate index based on pollution and heat stress areas and areas with compensating effects¹⁶

Source: own figure based on data from the City of Karlsruhe and the Nachbarschaftsverband Karlsruhe.

The hatching shown in the map is taken up in the subject maps for susceptibility and coping capacity

¹⁶ In some city districts the map shows deviations or contradictions in the urban climate to other studies such as were and are being carried out in Karlsruhe as part of the urban planning framework for climate change. This is due to the fact that average values are used at city district level. In some cases parts of the city district could be severely affected although – due to green spaces in other parts – they are not identified as such. However, an aggregation of the information from the urban climate map (NKV 2011) was still considered useful in order to illustrate the UHI along with the relevant administrative boundaries.

4.2 Vulnerability of the population to heat waves

In line with the concept explained in Section 2.3.1, the vulnerability of the population is assessed by the components *exposure*, *susceptibility* and *coping capacity*. Referring to these components, figure 9 gives

an overview of the topics, indicators and criteria of relevance for the population which will be explained in the following sections.

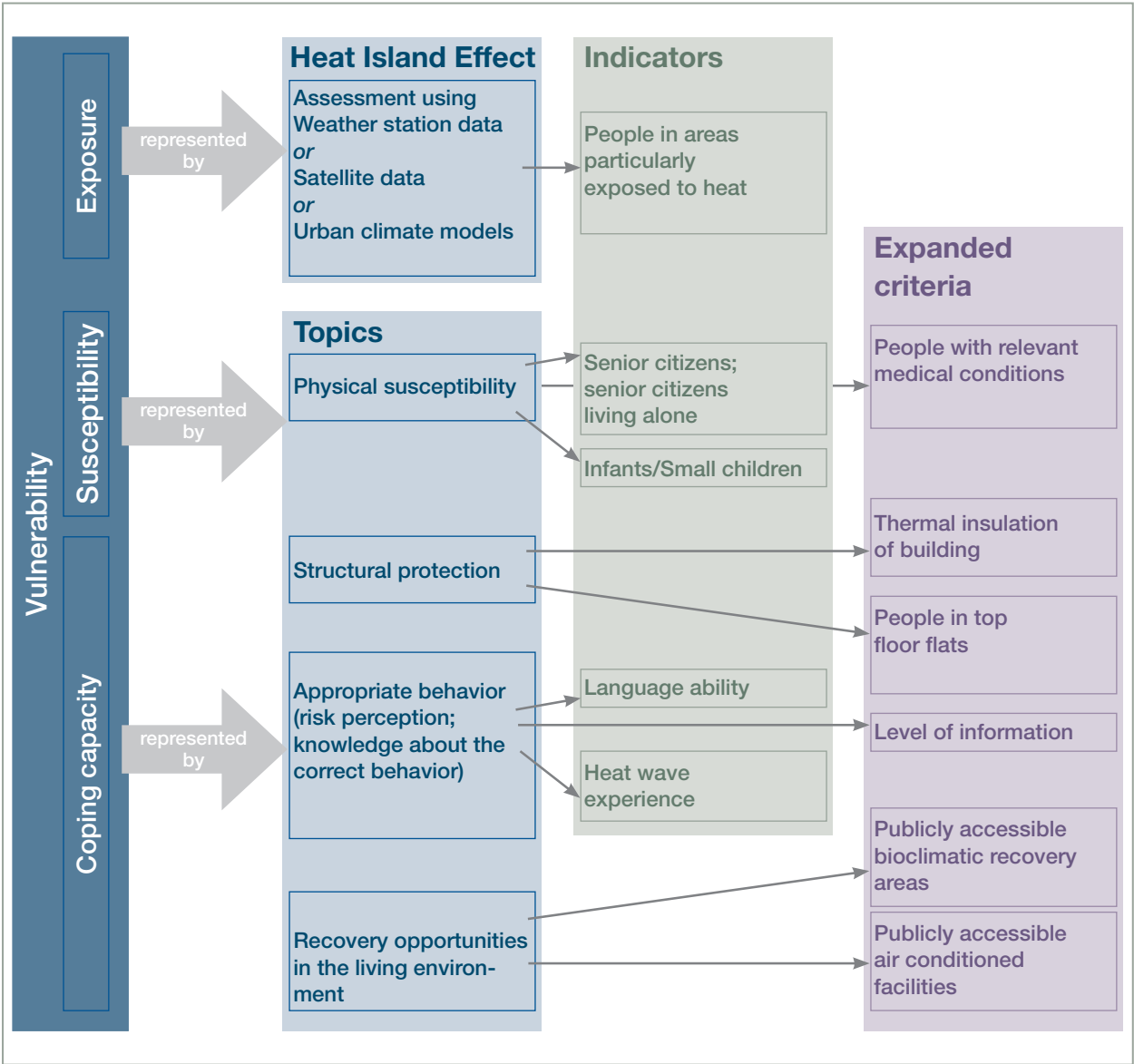


Figure 9: Topics, indicators and criteria for assessing the vulnerability of the population to heat waves
Source: own figure.

First "topics" which are of relevance for the susceptibility and coping capacity of the population to heat stress (see Figure 9) were identified from a thorough search of the literature and from workshops and expert interviews.

The susceptibility of the population is represented by the topic *physical susceptibility*, i. e. the physical conditions (age, health) which define the body's sensitivity to heat stress.

For coping capacity, the topics used were *structural protection*, that is, structural conditions which reduce or ameliorate the penetration of heat into the building, *appropriate behaviour (awareness of risk/knowledge about adaptive behaviour)* and *recovery opportunities in the living environment* (bioclimatic recovery areas or air conditioned facilities).

Indicators and/or expanded criteria were identified for each topic which are presented in boxes in the following sections. Indicators should enable state-

ments about the indicandum which is actually of interest (in this case, vulnerability) if the indicandum cannot be measured directly (cf. e. g. Birkmann 2004). The indicators selected here can usually be shown in a spatially differentiated manner e. g. at city district level by using data from the local authority statistics. However, for assessing vulnerability "expanded criteria" are also important which, in most municipalities, cannot be simply mapped from the local authority statistics because there is no suitable data set e. g. at city district level. The distinction between "indicators" and "expanded criteria" thereby refers to their operationalisability but does not reflect any difference in the importance of the information. Data for the "expanded criteria" is also recorded in some municipalities, or could be recorded generally in future. In principle the relevant data could be made available by a specially conducted survey (e. g. household survey). Furthermore, it is important to take these criteria into account in connection with measures such as information campaigns for informing the public.

4.2.1 Exposure

Based on the methods for determining the urban heat island effect (UHI), the exposure of the population can now be assessed in a second step. Any of the

methods presented (except the population density) can be used for this (see Table 3).

Indicator: Exposure – population in areas that are strongly exposed to heat

Recording unit: e. g. city district

Measurement unit: e. g. population density in city districts with a very high urban climate index

Relevance: The exposure, here the part of the population that lives in areas that are strongly exposed to heat, is a highly relevant component of vulnerability. The identification of areas with a high UHI and the population living in these areas is basic information for protection measures against impacts of a heat wave. With this information, measures can be implemented to reduce the UHI, as well as to better cope with the impacts of a heat wave.

Technical notes:

In order to identify the exposure of the population to the UHI, the results concerning the spatially different effects of the UHI (estimation of the UHI based on remote sensing data or urban climate models, see chapter 4.1) are intersected with population data. It must be pointed out that in the method explained under 4.1.1 on estimating the UHI using weather station data, the population density is already used as an explaining variable. Thus, in this case, the aspect of exposure is already included in the result of the UHI estimation.

The estimation of exposure refers to the resident population, as there is frequently no reliable and up-to-date data on workplaces per spatial unit. Further, the other indicators and criteria refer to the resident population as well. However, it would be reasonable, besides the resident population (*population at night time*), to also survey the people with an exposed working place (*population at daytime*) and to consider them in the exposure assessment.

Source of data: Local authority department of statistics; concerning data sources for estimating the UHI see chapter 4.1.

In the following example of the City of Karlsruhe (see Figure 10), the assessment of exposure is based on the calculation of the urban heat island effect using an urban climate model. The map shows data on population density combined with the values for the urban climate index.

If the population density as an independent variable was used for the assessment of UHI, this step is omitted. The population density then represents both the difference in the UHI and the exposure of the population.

In city districts with a high urban climate index value and a high population density there are therefore particularly large numbers of people exposed to heat stress. Figure 10 shows that this applies to individual city districts in the inner city area of Karlsruhe. However, some city districts are also characterised by areas with a high urban heat stress although the average population density is relatively low (e. g. "Rheinhafen" in the western part of Karlsruhe). To what extent workplaces or facilities with socio-economic service infrastructures such as old people's homes are found in these exposed city districts must be checked for individual cases.

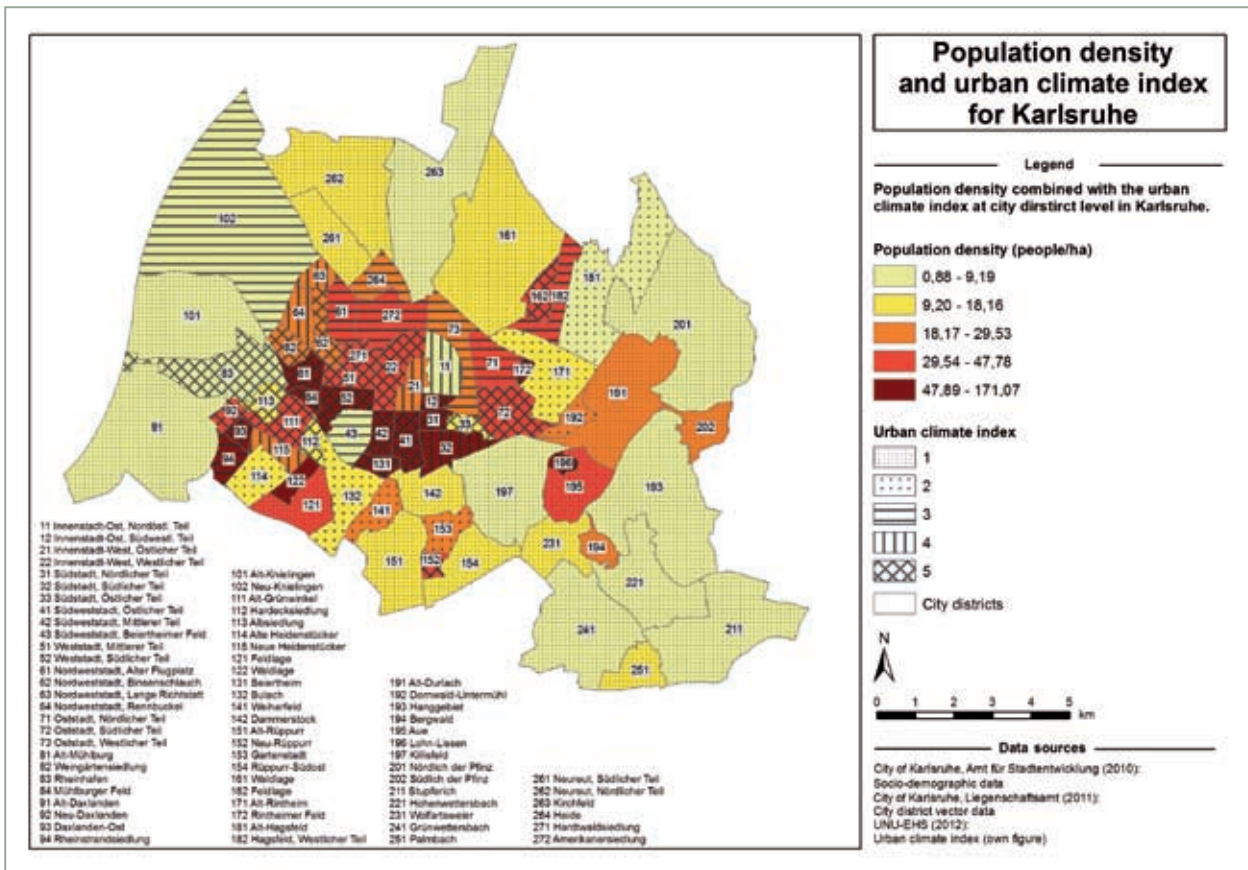


Figure 10: Exposure to heat waves: population density and urban climate in Karlsruhe

Source: own figure based on data from the City of Karlsruhe.

Potential measures at municipal level for reducing the urban heat island effect:

The options available to the local authority for reducing exposure to heat stress consist primarily in reducing the urban heat island effect by means of structural and town planning measures (Memon et al. 2008, Gill et al. 2007, Solecki et al. 2005, Corburn 2009). A

series of respective measures such as defining limits for building development or the preservation and creation of green/open spaces is given for example in the "Handbuch Stadtklima" (MUNLV 2010).

4.2.2 Susceptibility

The topic of *physical susceptibility* of the population to heat stress is discussed below using the indicators

- Senior citizens; senior citizens living alone
- Infants/small children

and the expanded criterion

- People with relevant medical conditions

(see also Figure 9).

Topic: physical susceptibility

There is a high physical susceptibility to heat stress if it is difficult to increase blood circulation and perspiration in order to keep the body cool under the ef-

fects of heat. Those affected are the elderly, children, those who are overweight, those confined to bed, people with particular diseases, those taking specific

drugs and people who consume alcohol or take recreational drugs (e. g. EPA 2006).

It would be desirable to have spatially refined information on the numbers of the specified groups in order to show the spatial distribution of physical susceptibility. There are usually age-related data at a

small-scale level e. g. city district level or smaller, but not for the other groups such as people with existing medical conditions or those taking specific medication. Therefore, the indicators *senior citizens (living alone)* and *infants/small children* are suggested as a first approximation.

Indicator: Senior citizens (living alone)	
Recording unit: e. g. city district	Measurement unit: Percentage of senior citizens (65 and older) of the population (living alone)
<p>Relevance: Older people are more susceptible to heat stress for health reasons as their body's natural heat regulation no longer functions so well and e. g. circulatory disorders can arise more easily (see Lissner et al. 2012; Diaz et al. 2002 and Medina-Ramón and Schwartz 2007 for more details). In addition, for older people living alone there is a higher probability that the necessary provision (e. g. provision of liquids) does not take place or symptoms of increased heat exposure are not recognised in due time (EPA 2006; Johnson et al 2005). There may also be existing medical conditions or physical restrictions which make it more difficult to modify behaviour during heat stress.</p>	
<p>Technical notes:</p> <p>The determination of a distinct age is difficult. For this indicator, studies of the WHO (2009), as well as Diaz et al. (2002), Jones et al. (1982) and Medina-Ramón et al. (2006) were utilized. However, different ages were identified in other studies, such as > 60 years (Applegate et al. 1981) or 70-79 years (Ellis et al. 1980).</p> <p>For the reasons stated, it is recommended considering both a spatial distribution of the elderly and also the group of senior citizens living alone. In addition, it might also be useful to include further factors such as the structure of buildings. In a study in Kassel, for example, the urban areas with a high percentage of over 60-year-olds living alone were identified primarily as those districts with a large number of detached houses surrounded by gardens with good shade which provide the option of avoiding the heat stress (Blättner et al. 2010).</p> <p>In addition it must be noted when interpreting the indicator that it includes people living in old people's homes whose vulnerability differs from that of people in private households due to the care provided.</p> <p>If the data contains an estimate of the change in the population by age groups at a small scale (e. g. city district), it is useful to integrate this as additional data in the vulnerability assessment in order to be able to include the relevant information in the planning process.</p>	
Source of data: Local authority department of statistics	

Figure 11 shows the percentage of senior citizens (65 and older) at city district level in Karlsruhe combined with the urban climate index. The percentage of senior citizens ranges from below 6 % to over 33 % so

that differences in the city districts are actually apparent. For example, the city districts No. 162 "Feldlage" in the north-east and No. 112 "Hardecksiedlung" in the south-west of the inner city have a high urban

climate index and also a high percentage of senior citizens, so that in these areas particularly large numbers of susceptible people could be affected by a heat wave.

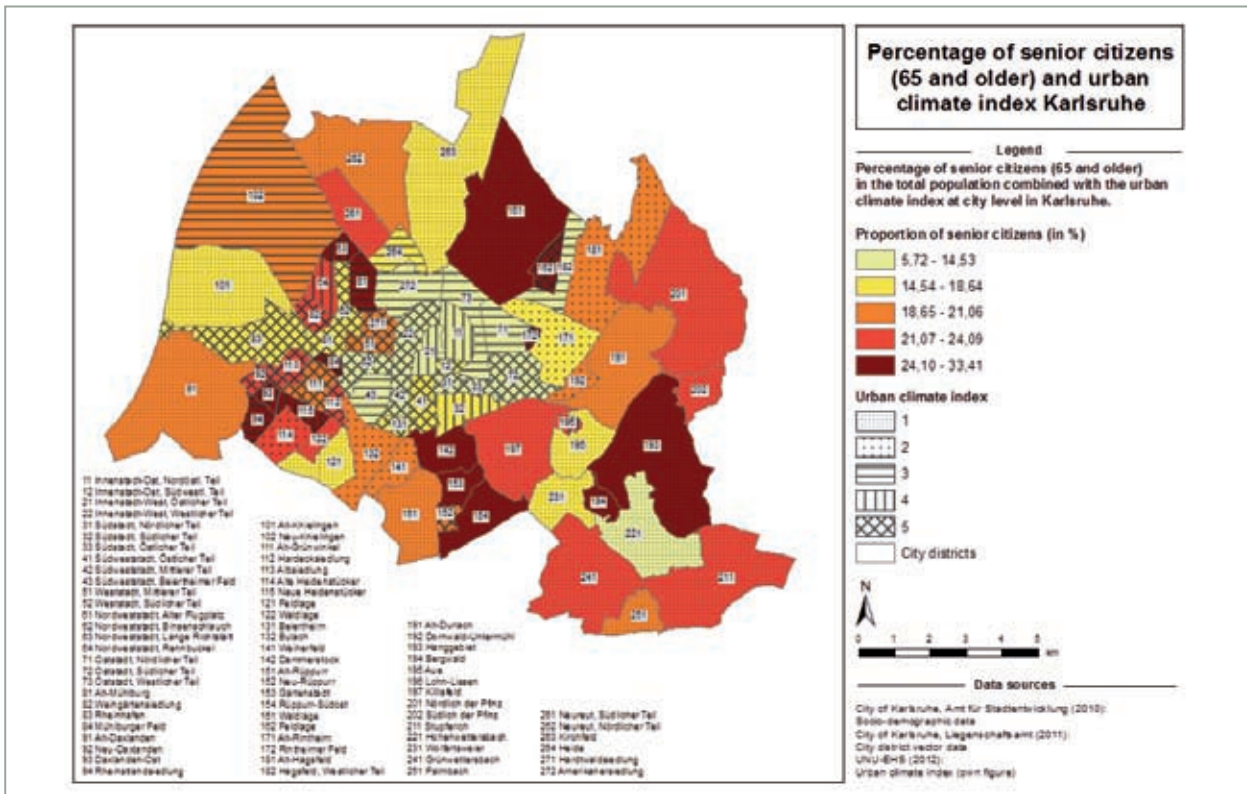


Figure 11: Percentage of senior citizens and urban climate index in Karlsruhe
 Source: own figure based on data from the City of Karlsruhe.

Indicator: Infants/Small children	
Recording unit: e. g. city district	Measurement unit: Percentage of infants/small children (aged 0-4 years) in the population
<p>Relevance: Small children are more susceptible to heat because the body's natural heat regulation is still unstable. Due to the greater surface to volume ratio, more heat can be transferred into the body from outside and in addition the ability to sweat is significantly lower in small children than in adults (Yaron and Niemeyer 2004).</p>	
<p>Technical notes: The term "infant/small child" does not have a unique definition. Studies show an increased risk for children between 0 and 4 years (Yaron und Niermeyer 2004; Danks et al. 2004; RKI 2003; Nakai et al. 1999) which is why this age range was also used here. If the data contain an estimate of the change in the population by age groups at a small-scale (e. g. city district), it is useful to integrate this data in the vulnerability assessment in order to be able to include the relevant information in the planning process.</p>	
Source of data: Local authority department of statistics	

Figure 12 shows the percentage of infants/small children in the city districts of Karlsruhe. The percentage (between 2.5% and 7%) appears to be relatively low overall. However, along with other factors, it is quite possible to make out differences. For example, the

city district "Albsiedlung" with a high urban climate index also displays a relatively high percentage of infants/small children and of senior citizens, so that a higher overall vulnerability can be expected here.

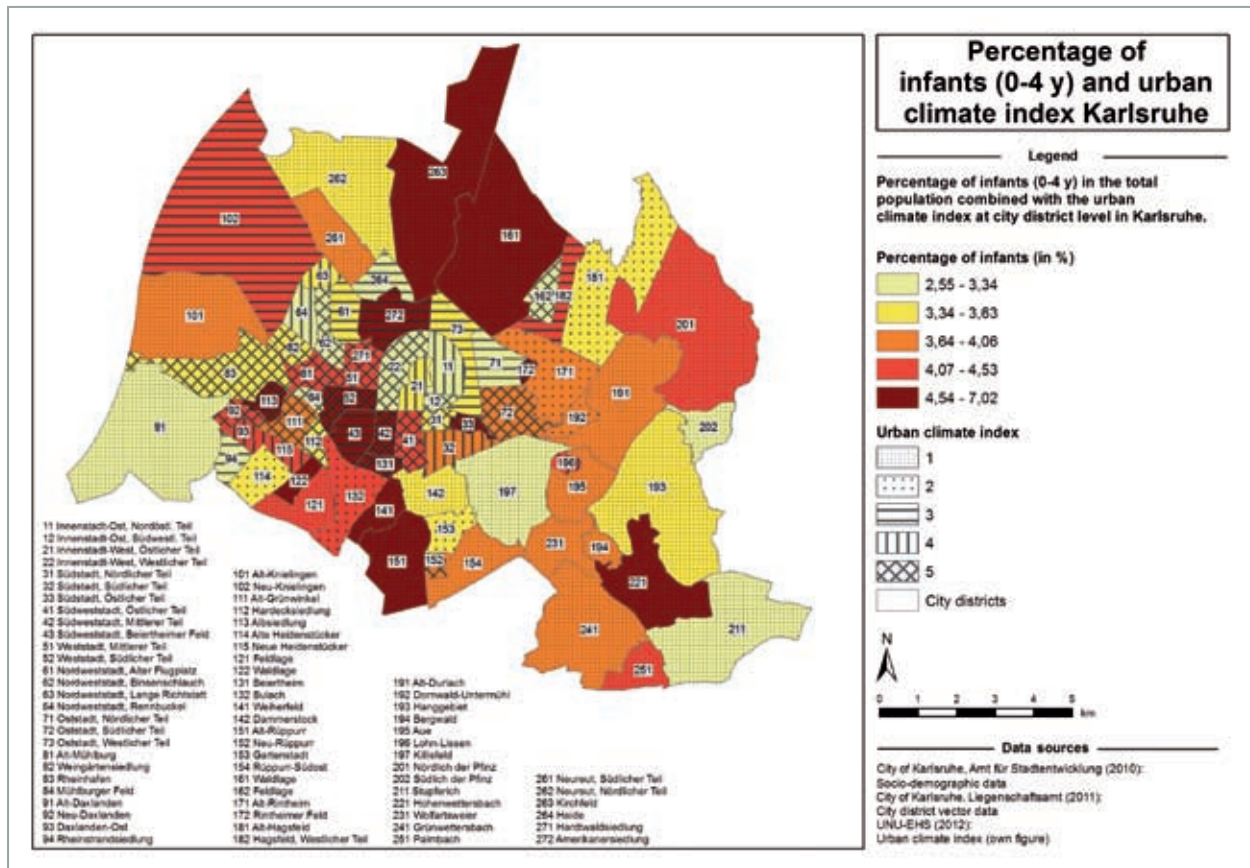


Figure 12: Percentage of infants/small children and urban climate index in Karlsruhe

Source: own figure based on data from the City of Karlsruhe.

Most municipalities do not have any spatially defined statistical data available for *people with relevant medical conditions*. These are therefore listed as a criterion but not as an indicator. A measurement and spatially refined presentation would therefore only

be possible based on the municipality's own surveys. However the criterion is important for the measures necessary – for example the provision of information and warnings in the case of an event:

Criterion: People with relevant medical conditions

Relevance: The functioning of the body's natural heat regulation is limited in people with particular diseases (e. g. heart disease, diabetes) and in people who take specific medication (e. g. for the treatment of high blood pressure, depression or sleep disturbances) (EPA 2006; Bouchama et al. 2007; Vandentorren et al. 2006; Medina-Ramón et al. 2006). However, in general there is little statistical data available on the relevant medical conditions and/ or use of medication at a small-scale level.

The following aspects also play a part in combination with physical susceptibility, but could not be included or only included indirectly in the indicators/criteria:

Limited mobility (e. g. being confined to bed) is a disadvantage with respect to dealing with heat waves since it is difficult to reach cooler places (Bouchama et al. 2007; RKI 2003; Vandentorren et al. 2006). There are also limitations due to e. g. cognitive disorders which must be taken into account in relation to rational decisions which determine actions to reduce heat exposure or the identification of symptoms caused by heat. This applies e. g. to the effects of drug or alcohol consumption (Kilbourne et al. 1982; Mücke et al. 2009). Besides elderly people living alone there are other socially isolated people, e. g. the homeless,

who are at an additional risk because heat-induced symptoms may not be recognised or only recognised belatedly (EPA 2006; Ramin und Svoboda 2009; Kovats und Ebi 2006).

In the USA, poverty (or a low socio-economic status) was identified as an important determinant for vulnerability to heat waves (Curriero et al. 2002). However, in studies on the 2003 heat wave in Europe, no significant link could be found between poverty and heat mortality (Kovats und Hajat 2008; WHO 2009). Nevertheless, a connection does exist to the extent that lower income groups of people tend to have more chronic illnesses or other medical risk factors such as overweight or mental illness, and they are likely to have more precarious living conditions (Kovats und Hajat 2008).

Potential measures at municipal area level for the topic of physical susceptibility:

In order to address physical susceptibility, the main measures available are early warning and information and awareness-raising in the public and with respect to those working in the relevant institutions.

The German Meteorological Service (DWD) has introduced a heat warning system which issues heat warnings at a rural district level. A warning is issued if a high heat stress, i. e. an apparent temperature of approx. 32 °C is forecasted for the early afternoon for at least two consecutive days. It is possible to subscribe to a newsletter for these warnings for individual rural districts. Heat warnings are important for a local authority in order to be able to pass them on to the public, but also for making their own preparations and for being able to take the necessary action. Groups which are particularly vulnerable to

heat should be identified and it is recommended to contact them or their carers directly (see also the topic on appropriate behaviour).

Recommendations for dealing with heat, particularly for the most susceptible groups of people and their carers have already been provided by various local authorities (e. g. public health departments). In order to be able to reach susceptible people (or their carers) in care institutions, an appropriate exchange of information needs to be guaranteed. It is therefore important to keep current data on institutions in which particularly vulnerable people (e. g. the elderly, homeless) stay. This will enable these people to be contacted directly in advance of a heat wave and given support during a heat wave (EPA 2006).

4.2.3 Coping capacity

The following indicators and expanded criteria are used and described for the coping capacity of the population to heat stress (see also Figure 9):

For the topic of *structural protection* the expanded criteria

- *Thermal insulation of the buildings*
- *People in top floor flats;*

for the topic of *appropriate behaviour (risk awareness; knowledge about adaptive behaviour)* the indicators

- *Language ability*
- *Heat wave experience*

and the expanded criterion

- *Level of information;*

for the topic of *recovery opportunities in the living environment* the expanded criteria

- *Publicly accessible recovery areas*
- *Publicly accessible air conditioned facilities.*

Topic: Structural protection

The indoor climate in living spaces and therefore the thermal insulation of residential buildings is an important factor for the vulnerability of the population to heat stress. However there is inadequate data about the connection between the type of house (and the thermal behaviour) and social vulnerability to heat waves. Contrary to this, links between living on the top floor and an increased mortality rate during heat waves have been demonstrated in e. g. studies in France and Philadelphia (Vandentorren et al. 2006; Mirchandani et al. 1996; Kovats and Hajat 2008).

It can be useful for recording structural protection in the context of heat waves to have a classification of residential buildings into types of buildings which represent different thermal behaviour. A building classification prepared by the Institut Wohnen und Umwelt (IWU) (institute for housing and environment) to identify the potential energy savings from thermal insulation measures for the German housing stock is based on the age of the building and the size of the building stock. The age of the building is important because common designs and typical construction components (e. g. window sizes) which influence the thermal features of the building occur in each

construction era. The size of the building influences the area of the thermal hull and its division into different components (IWU 2005). In 2010, a representative random sample survey of residential buildings in Germany was carried out to determine the occurrence of different types and their renovation status (IWU 2011). A record of these types of residential buildings at municipal level could also provide an indication of structural protection in relation to heat waves.

A number of studies has demonstrated a connection between the year of construction of houses and an increased risk from heat stress (Vandentorren et al. 2006; Blättner et al. 2010; Lecomte und Penaster 2004), although these studies identified differing construction years. Studies carried out by the City of Cologne, for example, showed that for this city three periods could be distinguished:

- Prior to 1975: tendency for a good insulation status due to subsequent renovation
- 1975-2004: tendency for a poor insulation status as no renovation carried out

- 2005 onwards: good level of insulation due to new legislation¹⁷ (Stadt Köln 2011).

In contrast, a study on the 2003 heat wave in France showed problems with buildings from pre 1975 in this context (Vandentorren et al. 2006). Studies in Kassel on heat-related health risks indicated that multiple family dwellings from the 1970s, 1980s and 1990s had particularly bad insulations (Blättner et al. 2010). The relevant links between construction year and thermal living conditions must first be investigated by the local authority before the criterion can be applied.

American studies often cite the availability of an air conditioning system in the flat as a factor which minimises risk (e. g. Semenza et al. 1996). Air conditioning systems in residential buildings are still very unusual in most European countries (Kovats and Hajat 2008; WHO 2009) and are therefore not used as an indicator or criterion here. However, an increase in the number of air conditioning systems is expected in the future, so that this criterion can also become relevant for Europe (Adnot et al. 2008).

Criterion: Thermal insulation of buildings

Relevance: The thermal insulation of (residential) buildings is of great importance for the vulnerability of their residents. According to various studies (for example IWU 2011), the thermal insulation is correlated with the year of construction, but the type of relationship differs depending on the study location. In other words, no generally applicable period for construction can be defined for good or bad thermal insulation. The correlation of construction year and thermal insulation must therefore be defined separately for each municipal area. Data on the year of construction were requested throughout Germany as part of the 2011 census of buildings and flats but are otherwise not generally available.

An improvement in the data base for thermal insulation can be achieved by recording the energy demand or energy consumption indices (according to the energy performance certificate). The classification according to construction year described above can contribute to this.

¹⁷ Legislation with higher requirements for energy savings (EnEV 2004 – German Energy Savings Act – in line with the EU Directive on energy efficiency in buildings).

Criterion: People living in top floor flats

Relevance: Top floor flats (especially those with pitched roofs) are particularly exposed to heat. If there is no potential for moving to lower floors, then an increased vulnerability of the residents, due to their living conditions, can be assumed (Vandentorren et al. 2006; Michandani et al. 1996; Lecomte und Penanster 2004).

In general there is no statistical data available on top floor flats. Simply recording the number of floors is not adequate as these rooms may not be inhabited at all, or the flat may cover several floors, thus providing an alternative. However, the criterion is very important for the estimation of vulnerability.

Potential measures at a municipal level for the topic of *structural protection*:

There are various structural measures available to improve thermal insulation in flats. This includes firstly thermal insulation which is actually aimed at saving energy but also reduces the penetration of heat from outside for a certain time (see e. g. projects by the Institut Wohnen und Umwelt¹⁸). In addition, shading the house wall with vegetation or structural elements (Akbari et al. 2001) and the use of light building materials or light colours on the walls can reduce the amount that buildings heat up (Gill et al. 2007). A positive thermal effect on buildings can also be achieved by having planted roofs (Kumar und Kauschik 2005; Palomo und Barrio 1998). These and other

structural/town planning measures for reducing heat stress are also e. g. compiled in the "Handbuch Stadtklima" (MUNLV 2010).

Increased implementation of the measures described can be achieved on the one hand with financial incentives through funding programmes and on the other hand through stipulations in building plans e. g. prescribing plantings and planting obligations for individual areas or for a development area or parts of it in accordance with para. 9 (1) no. 25 of the Federal Building Code (BauGB) (MUNLV 2010).

Topic: Appropriate behaviour during a heat wave (risk awareness; knowledge about correct behaviour)

For the topic "appropriate behaviour", risk awareness and the understanding of risk as well as knowledge about appropriate behaviour are of key importance. Language ability is important in understanding early warnings and recommendations for action. The level of information and relevant past experience in dealing with heat waves are considered of relevant importance for the behaviour during or prior to a

heat wave. For this topic, in a first approximation, *language ability* and *experience in dealing with heat waves* are therefore suggested as indicators and the *level of information* as a further criterion. The indicator *language ability* can only be recorded indirectly from the percentage of foreign fellow citizens, on the assumption that knowledge of the German language is less well developed in this group.

¹⁸ <http://www.iwu.de/forschung/energie/abgeschlossen/>

Indicator: Language ability – initial approximation: percentage of foreign fellow citizens

Recording unit: City district

Measurement unit: Percentage of foreign fellow citizens (= people without German nationality) in the population

Relevance: Often information on preparing for an incident and during the incident itself is only communicated in the German language. This can be a problem for foreign fellow citizens or put them at a disadvantage. Sections of the population with poorer knowledge of the German language then have less chance of preparing themselves and of responding in accordance with advice during the incident (cf. e. g. Geenen 2010; Wilhelmi and Morss 2012; McGeehin and Mirabelli 2001).

Although large numbers of people of non-German nationality have good German language ability and conversely some people of German nationality speak very little German, there is a correlation between nationality and German language ability.¹⁹ As direct data on language ability are not generally available, this correlation can be used as a first approximation in order to e. g. identify city districts where information on heat stress might be helpful in foreign languages.

Technical notes:

Besides language, other correlations between foreign fellow citizens and vulnerability can sometimes be identified, for example in relation to economic resources, cultural contexts or family structures (cf. e. g. Geenen 2010, Medina-Ramón et al. 2006, Schwartz 2005). Within the framework of the KIBEX project it has not been possible to prove these correlations adequately and they have therefore not been given further consideration for the set of indicators.

Source of data: Local authority department of statistics

¹⁹ In the UNU-EHS household surveys, the percentage of foreign fellow citizens who can speak at least moderately good German (on a scale of 1 to 5, 3 = moderate), comes to 38.7% in total. Similar figures were found in the German Socio-Economic Panel (SOEP) – according to this, in 1999 35% of foreign fellow citizens could not speak good German (http://www.diw.de/deutsch/wb_24/01_deutsche_sprachfaehigkeit_und_umgangssprache_von_zuwanderern/30819.html, 28.02.13).

Figure 13 shows the percentage of foreign fellow citizens in Karlsruhe at city district level in combination with the urban climate index. The percentage varies between below 4% to over 30%. In city districts with a high percentage of foreign fellow citizens, information in foreign languages could therefore be useful. Providing information on prevention in foreign

languages in this context was endorsed in the expert interviews. In Cologne, when carrying out the household surveys, it also appeared that information relating to prevention might be required in other languages, especially in districts with a high percentage of foreign fellow citizens.

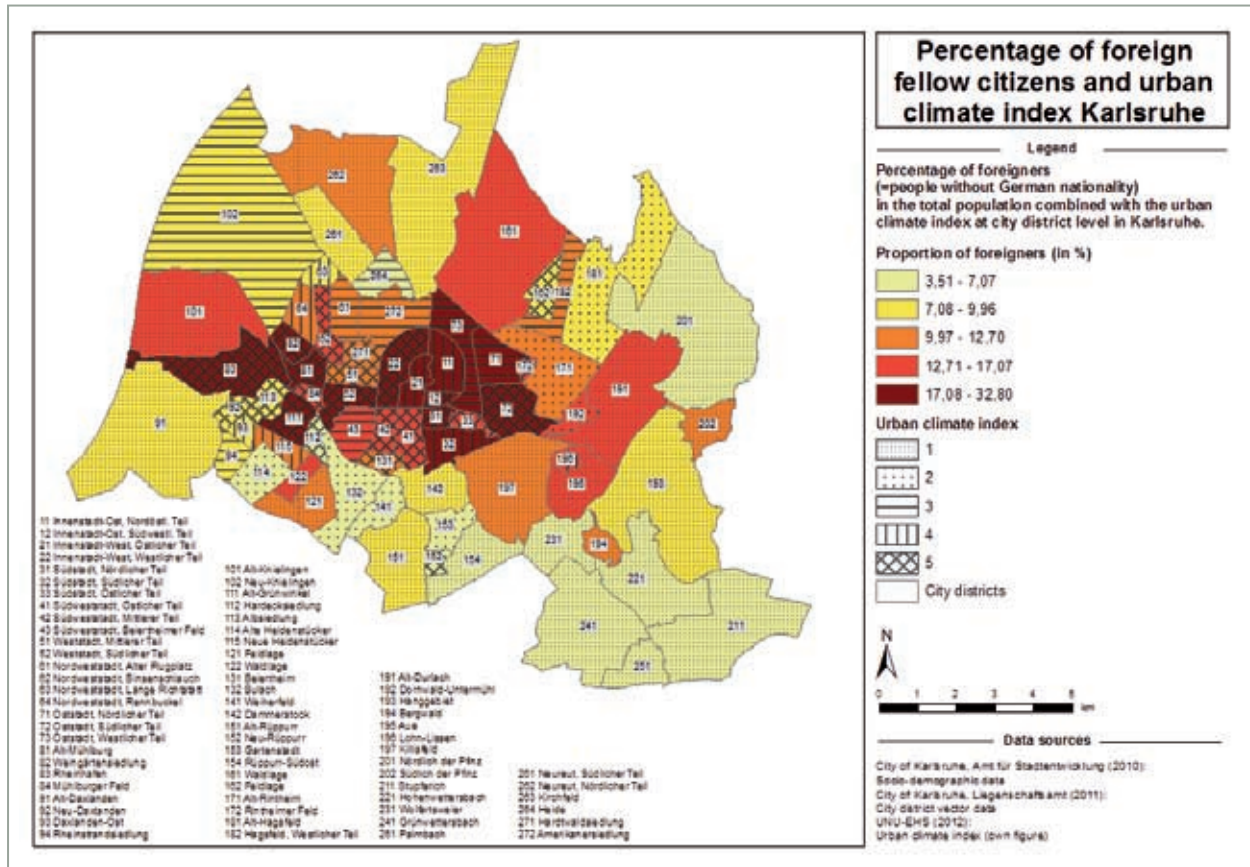


Figure 13: Share of foreign fellow citizens and urban climate index in Karlsruhe
 Quelle: eigene Darstellung basierend auf Datengrundlagen der Stadt Karlsruhe.

When it comes to behaviour in dealing with a natural hazard, it is often of importance whether the people affected have already experienced an event of this

kind. This is why the *experience in dealing with heat waves* is seen as a relevant indicator:

Indicator: Experience in dealing with heat waves – living in the city/municipality at least since the last heat wave event

Recording unit: City district

Measurement unit: Percentage of people who have lived in the city/the municipality at least since the last heat wave event

Relevance: The UNU-EHS household surveys were able to verify that people who had already experienced a heat wave tend to be in a better position to respond appropriately. They tend to change their daily behaviour in favour of a better approach to a heat wave.

A suitable assessment can – considering uncertainties, see below – be made using the time of residence at the place of residence in relation to a reference event. The reference event can be selected using heat-related excess mortality in the heat wave period (excess mortality = an increased mortality rate of a specific section of the population in comparison to the expected mortality rate). The public health department in Cologne, for example, identified an increase in mortality in August 2003 of 16.5% in comparison to previous years (Koppe et al. 2004).

Technical notes:

Pre-classified data on residence period (<2 years, 2-<5 years and 5-<10 years; reporting year 2009) is available for Karlsruhe, for example. As the heat wave of 2003 is to be used as the reference event, the classification “resident since 2004 or earlier” and “others” is used.

Depending on the context of the municipality, the indicator can lead to some inaccuracies, e. g. from newcomers who have already experienced a heat wave somewhere else. Furthermore, people's age can also have a significant effect on past experience. On top of this, data may only be available for the period of residency in the current flat, so that moves within the city cannot be taken into account.

For the reasons mentioned, this indicator was considered to be controversial in the expert interviews and workshops carried out as part of the KIBEX project. However, in the opinion of the majority of experts, these inaccuracies could be accepted, as it was viewed as very important to take account of the aspect of *experience*.

Source of data: Local authority department of statistics

Figure 14 shows the percentage of residents in Karlsruhe who have lived in the city since 2004 or earlier (using the above-mentioned pre-classified data in relation to the reference event of the heat wave of 2003). The map shows a clear division, with a relatively short residence period in the inner city, a

higher residence period in the east/southeast and the highest values in the southern districts of the city. The inner city areas with a higher urban climate index and a high number of newcomers represent areas with higher susceptibility in this context, due to (supposed) less past experience.

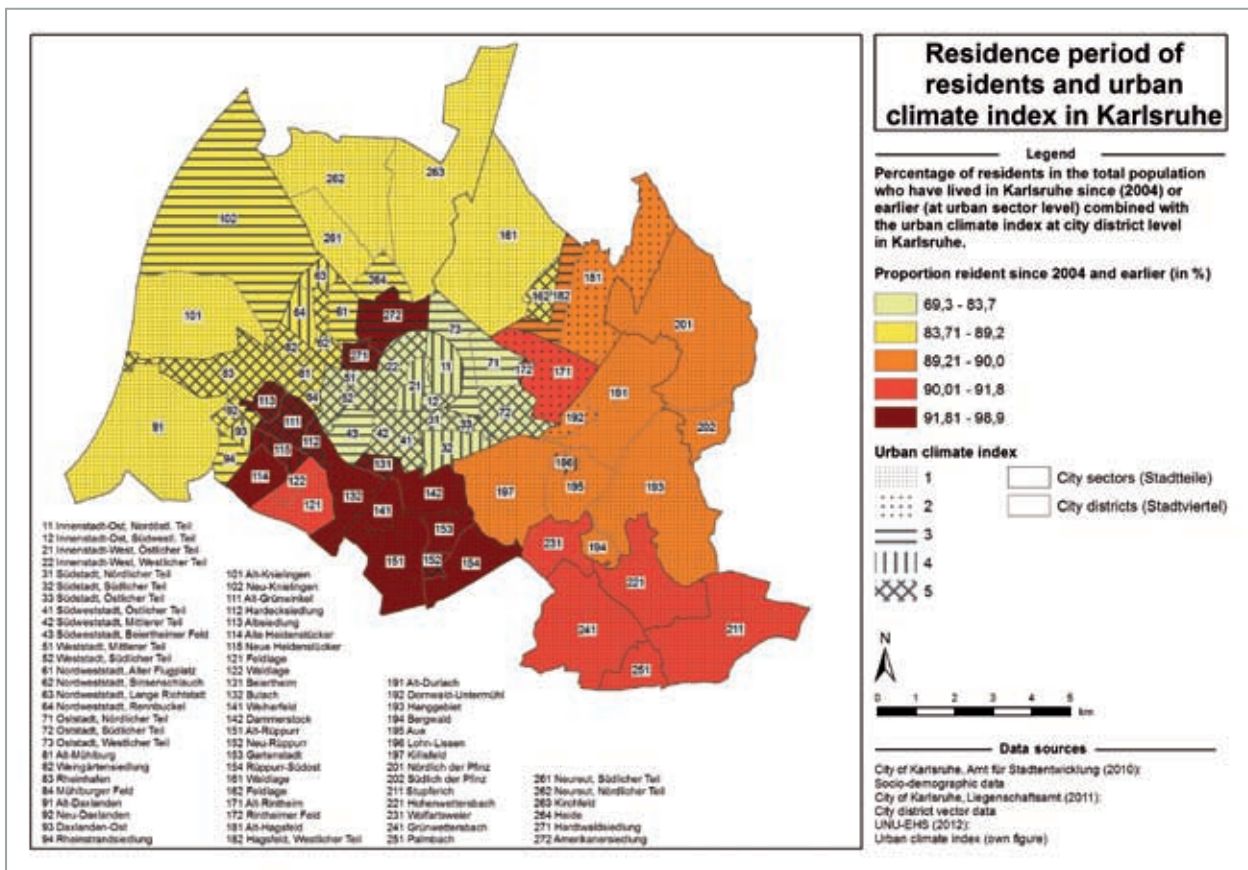


Figure 14: Percentage of residents who have lived in Karlsruhe since 2004 or earlier combined with the urban climate index
Source: own figure based on data from the City of Karlsruhe.

In the context of heat waves, the level of information is also very important for appropriate behaviour, but cannot be shown at a small scale using statistical data:

Criterion: Level of information on dealing with heat waves – level of education

Relevance: Access to information is considered an important factor in terms of vulnerability towards natural hazards (Cutter et al. 2003). As part of the KIBEX project, the UNU-EHS household surveys were able to show that people with a higher level of education would be more likely to alter their daily behaviour to deal appropriately with a heat wave. The level of education (both the type of school-leaving qualification and the type of highest educational qualification) strongly depended on the degree of information of the interviewees on the topic of climate change, so that data on the level of education, if available, also enables statements on the level of information as a first approximation. However, data on the level of education of the population is generally not recorded at a small-scale level (e. g. city district level).

Various studies also use level of education as an indicator as it represents a measure of people's socio-economic status being connected to susceptibility to heat waves (e. g. O'Neill et al. 2003).

Curriero et al. (2002) and Medina-Ramón et al. (2006) show a significant correlation between people with little education and increased heat-related mortality for the US²⁰. Presumably this correlation is linked to other factors, such as a lower average state of health and poorer living conditions with poor structural protection from heat (Medina-Ramón et al. 2006). In addition, this group of people tend to be employed in physically demanding occupations (Greenberg et al. 1983; O'Neill et al. 2003).

Possible measures at a municipal level for the topic of *appropriate behaviour*:

There are various options for the local authority to provide information on appropriate behaviour. In terms of prevention, use could be made e. g. of leaflets distributed to public institutions (e. g. libraries, schools, community centres) or websites. On the other hand, for early warning and dissemination of current information during a heat wave it is advisable to use radio and television as the principal means of communication. With reference to the indicator *experience in dealing with heat waves*, it could be useful especially for cities with high exposure to heat waves (high incidence of UHI) to draw the attention of newcomers to the problem, as a first step.

For example, the City of Cologne provides general information and tips on dealing with heat stress on their website²¹. In addition, a guide can be downloaded about this²² specifically for senior citizens, people who are ill and those in need of assistance and

their carers. The corresponding information is also available for the City of Karlsruhe. On its website, for example, there is information²³ on heat stress for relatives, friends and neighbours on providing support to older people, especially those living alone. In addition, information is available to download for old people's and nursing homes²⁴ and for outpatient services and relatives.

Another option for improving the way in which heat waves are dealt with by the public is to set up a telephone hotline, where information can be obtained for questions on matters to do with heat. Further, due to the possible language barriers mentioned, information in foreign languages is useful for e. g. city districts with a particularly high percentage of foreign fellow citizens or with a high percentage of people with an immigrant background.

²⁰ Medina-Ramón et al. (2006) refer to a high school leaving examination or less in the US system.

²¹ Stadt Köln (n.d. a): Sommerhitze. Available at: <http://www.stadt-koeln.de/3/gesundheit/sommerhitze/> (10.01.2013).

²² Stadt Köln (n.d. b): Was tun bei Hitze? Informationen und Hinweise für Seniorinnen und Senioren, Kranke und Hilfebedürftige und deren Betreuerinnen und Betreuer. Available at: <http://www.stadt-koeln.de/mediaasset/content/pdf53/1-6.pdf> (10.01.2013).

²³ Stadt Karlsruhe (2011): Hitzeprävention. Available at: <http://www.karlsruhe.de/b3/soziales/personengruppen/senioren/seniorenwegweiser/unterstuetzung/sicherheit/hitzepraevention.de> (10.01.2013)

²⁴ Landkreis Karlsruhe (2006a): Was ist bei großer Hitze zu beachten?. Available at: http://www.landkreis-karlsruhe.de/media/custom/1076_139_1.PDF (10.01.2013).

²⁵ Landkreis Karlsruhe (2006b): Was ist bei großer Hitze zu beachten? II. Available at: http://www.landkreis-karlsruhe.de/media/custom/1076_138_1.PDF (10.01.2013).

Topic: Recovery opportunities in the living environment

Recovery opportunities in the living environment are considered to be primarily *publicly accessible bioclimatic recovery areas* and *publicly accessible air-conditioned facilities*.

Criterion: Publicly accessible bioclimatic recovery areas close to living accommodation

Relevance: Public green spaces in the vicinity of residential buildings reduce the urban heat island effect by producing cold air during the night (e. g. Henschel et al. 1969, Vandentorren et al. 2006) and can be used as recreational areas during the day. Areas with the ability to produce cold air are already included in the assessment of the UHI (see Section 4.1) and therefore in the exposure analysis. But the additional recreational function of such areas is important for coping capacity. However, several factors are important here, so that a simple measurement based on administrative units by using the data normally available is not possible.

In order for an area to be useful for recovery during heat stress, it has to supply shade, be publicly accessible and has to be reached on foot without hindrances. Areas of open water provide an additional improvement to the microclimate. Structural diversity in the recovery areas may also improve the visitor's sense of well-being.

The publicly accessible green spaces in the City of Karlsruhe are currently being evaluated in terms of their bioclimatic recovery function taking the above-mentioned criteria into account.²⁶

This is based on vector and matrix data sets in GIS format, including the ATKIS (Official Topographical Cartographic Information System) landscape plan, a tree register and aerial photographs. The evaluation is based mainly on public accessibility, the ability to be reached on foot, the percentage of shade and the presence of open water areas.

The precision of the results can vary depending on the availability of data and financial means. For financial support, options could be checked for public funding in connection with climate change.

²⁶ Produced by GEO-NET Umweltconsulting GmbH and berchtoldkrass space&options in cooperation with the Karlsruhe town planning office as part of the KLIMOPASS project, <http://www.lubw.baden-wuerttemberg.de/servlet/is/69206/> (11.02.13)

Criterion: Publicly accessible air-conditioned facilities

Relevance: Air-conditioned rooms provide places of refuge during severe heat stress. Air conditioning systems in flats are not common in Germany, so that publicly accessible facilities with air-conditioned rooms offer the opportunity to recover and to temporarily escape the heat stress.

Relevant data, i. e. on the location, reachability and accessibility also with respect to opening hours of the facilities are not generally available but could be collected and – in agreement with the relevant facility – displayed on a map. At the same time it must be kept in mind that this can only be a short-term coping measure, as air conditioning systems increase power consumption on the one hand and can also give rise to health problems due to the abrupt change in temperature. In the long term, construction measures should be considered that represent a more sustainable solution.

Possible measures at a municipal level for the topic of recovery opportunities in the living environment:

Support for recovery opportunities in the living environment in the form of publicly accessible bioclimatic recovery areas can potentially be achieved in combination with measures for other aims (including a reduction of the urban heat island effect). Competition for land use generally limits the extent of inner city green spaces. Options for safeguarding suitable areas are provided in the relevant documentation in the regional plan, land-use plan and the designations in the development plans (e. g. for parks, areas of woodland) (MUNLV 2010).

For recovery opportunities in terms of air-conditioned rooms, an evaluation could be made as to whether suitable facilities such as air-conditioned community

centres, shopping centres etc. could be listed with their location and opening times and the information made available to the public. For example in Philadelphia, USA, in cases of extreme heat stress, public buildings and also certain private ones are defined as cooling shelters and appropriate transport provided to the buildings. In addition, the opening times of air-conditioned public buildings are extended. A list of the facilities with addresses and opening times can be accessed on the Internet (EPA 2006; Philadelphia Office of Emergency Management 2012). With measures of this kind the conflict of interests between energy saving/climate protection and the use of air conditioning must be pointed out.

4.3 Vulnerability of critical infrastructure to heat waves

As already described in Section 2.3.2, various organisations and facilities come under the definition of critical infrastructures. These include socio-economic service infrastructures on the one hand, where the focus in what follows is on those institutions catering for a large number of susceptible people who may

be in need of help in the event of a heat wave. As far as the basic technical infrastructure is concerned, the further analyses focus on the electricity supply which, if it were to fail, would significantly impair the functioning of society and would therefore affect the population.

4.3.1 Vulnerability of socio-economic service infrastructures

The analysis of the vulnerability of socio-economic service infrastructures proceeds from the assumption that it can represent hot spots in social vulnerability if the relevant facilities are exposed to heat waves. While this views buildings as potential *vulnerable elements* which can be intersected with the UHI, it is the vulnerability of the people in the buildings which is actually the main focus.

Like the assessment of exposure of the population, the exposure assessment of socio-economic service infrastructures is also based on the calculation of the urban heat island effect. The urban climate index (see Section 4.1.3) is used as a basis with which the relevant service infrastructures can be intersected²⁷.

The buildings of relevance identified were institutions which cater for a large number of susceptible people. As explained in the preceding chapter, this mainly involves infants/small children and elderly people whose natural heat regulation does not yet or no longer function optimally under the effects of heat stress. In line with this, nurseries (day care centres) as well as elderly and nursing homes were defined as susceptible institutions. In addition, people with specific existing medical conditions such as heart and

circulatory diseases are considered to be susceptible to heat. For this reason hospitals were also classified as susceptible service infrastructures. The specified groups also often have restricted mobility and may not be able to seek out cooler shady outside areas or are reliant on help/care for coping with their daily needs. While the care available in the service infrastructures mentioned is advantageous as the susceptible people are better looked after there than if they were at home alone, at the same time it must be assumed that the care personnel themselves may be affected by the heat and may reach the limits of their capabilities due to the additional care needs, as it is one finding of the expert interviews.

For the reasons mentioned, it is important to know the differing degrees of exposure of the institutions in order to be able to target measures appropriately. In addition, when selecting locations for new buildings, the urban climate could be taken into account as a criterion in the future. Figure 15 shows the exposure of socio-economic service infrastructures in Karlsruhe. Irrespective of the degree of exposure, local authorities should draw attention to existing heat warning services such as that from the DWD where they can register.

²⁷ In order to guarantee a consistent presentation the urban climate index is made use of again. However, the results of the other methods for assessing the urban heat island effect can also be used for the intersection.

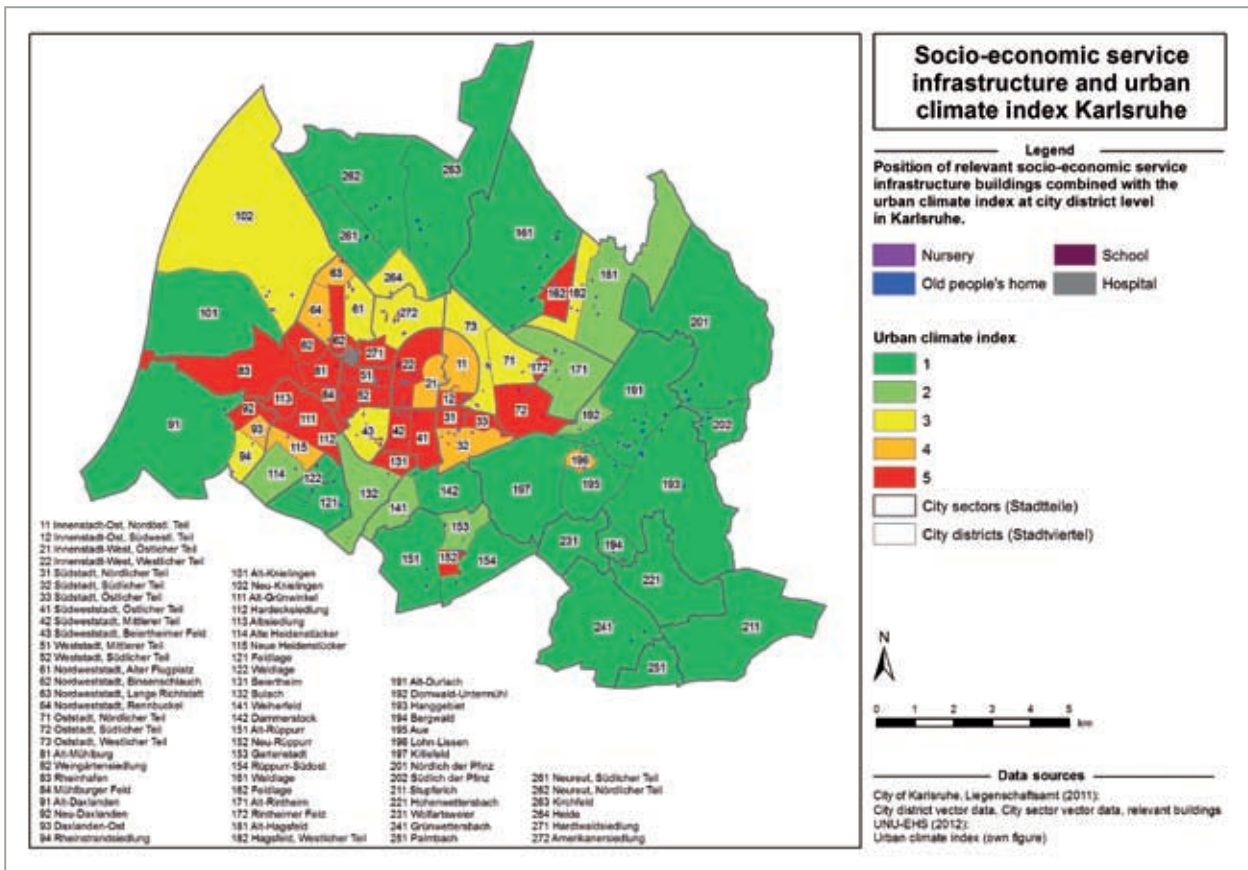


Figure 15: Socio-economic service infrastructure and urban climate index in Karlsruhe

Source: own figure based on data from the City of Karlsruhe.

It is noticeable that hospitals (90 %) and elderly homes (55 %) in particular are located in parts of the city which are subject to high climatic stress and air pollution, as also shown by Table 8. However should

be noted that the real susceptibility also depends on the availability of air conditioning systems in the buildings.

Table 8: Number and percentage of buildings of socio-economic service infrastructures in different urban climate classes in Karlsruhe

Building	Total number and (proportion in %)	Urban climate index				
		1	2	3	4	5
Hospitals	50	2 (4 %)	0	4 (8 %)	0	44 (88 %)
Nurseries	151	49 (32 %)	12 (8 %)	23 (15 %)	13 (9 %)	54 (36 %)
Schools	246	68 (28 %)	29 (12 %)	31 (13 %)	20 (8 %)	98 (40 %)
Old people's homes	65	21 (32 %)	2 (3 %)	3 (5 %)	3 (5 %)	36 (55 %)

Source: own calculations based on data from the City of Karlsruhe

4.3.2 Vulnerability of the electricity supply

As described at the outset, the vulnerability of various sectors can usually be analysed in the components of *exposure*, *susceptibility* and *coping capacity*. However, this form of analysis cannot be applied to the electricity supply and its vulnerability to heat waves. In the first instance this is due to the fact that the system components are hardly affected by any physical damage but that heat waves, in particular in combination with concurrently occurring drought, tend to have a longer-term effect on the processes of the whole system. At the same time, heat waves extend over a very large area in most cases. In the summer of 2003, for example, the whole of (Western) Europe was exposed to heat stress. Small-scale differences as found in relation to the UHI have no significant effect on the processes involved in the electricity supply.

Nevertheless, in relation to the susceptibility and coping capacity of the system, some important criteria can still be defined which determine the vulnerability of the electricity supply to heat waves/droughts. These are, however, primarily of regional relevance. The level of rivers and their water temperatures are of key importance in this context. Low river levels affect shipping and therefore particularly coal-fired power plants, as their supplies are restricted. River water temperatures affect the cooling of power plants. The abstraction of cooling water may need to be reduced during severe and long-lasting heat waves in order to prevent further temperature increases of rivers which are already warm due to the heat and low levels and thus to prevent major damage to eco-systems²⁸ (see also Kropp et al. 2009). This means that the opera-

²⁸ Above a specified water temperature the abstraction of cooling water has to be restricted in order not to pose a threat to the attainment or preservation of the good or very good ecological condition or potential of the water body. However, exemptions can apply in certain cases in order to avoid an energy bottleneck, such as in Baden-Württemberg in the summer of 2003 (cf. Landtag von Baden-Württemberg 2003).

tion of power plants may be limited or interrupted. In the summer of 2003, the output of conventional German power plants had to be reduced by an average of 45%. At the same time, water and wind power was not able to compensate for the deficit due to low amounts of water and wind (BfG 2006). This potentially reduced supply due to heat/drought can be accompanied by an increased demand from trade and industry and from private households e. g. due to air-conditioning systems (Bundesregierung 2008; Olonscheck et al. 2011) which increases *susceptibility*. Deficits of this nature could in principle be compensated via the European power grid. However, due to the geographically extensive occurrence of heat/drought, other countries besides Germany could be affected so that this is also only possible to a limited degree. In summer 2003, for example, Switzerland and France had to reduce their electricity exports by 15-20% (BfG 2006).

Only limited *coping capacities* are available to deal with these potential bottlenecks in the power supply. One of the few possible options is the uncoupling of large consumers from the grid (compare e. g. VKU and BDEW 2012), in order to maintain system safety and to prevent possible cascading effects.

Susceptibility and coping capacity of electricity supply systems towards heat waves depend to a big extent on the set-up of supply with respect to the sort, amount and functioning of generation capacities and their heat related limitations. Accordingly, effects of retrofitting respective set-ups e. g. for mitigation reasons can be assumed to have effects on the system vulnerability (see e. g. Hadjipaschalis et al. 2009 or Divya und Østergaard 2009). In order to develop long-term vulnerability reducing adaptation strategies to heat waves, the (potentially positive) effects (see Sperling et al. 2011) of a decentralization of supply should be analyzed while considering respective new challenges for network control.

At the same time, municipalities can hardly (except e. g. through operating municipal utilities) influence

set-up and restructuring of electricity supply systems which is (through liberalization and privatization) today mainly determined by private operators while the state is responsible for the strategic promotion, supervision and surveillance (see e. g. Monstadt 2008). Municipal measures with respect to potential electricity supply failures can thus be identified in the field of preventative civil protection planning encompassing amongst others the development of energy saving plans or communication strategies. Municipal vulnerabilities towards electricity supply failure and potential Disaster Risk Management criteria and measures are thus taken up in Chapter 6.

Particularly difficult conditions arise if a natural hazard triggers a power failure or coincides with one (independently of the trigger). In the case of a concurrent heat wave and power cut, the failure of cooling systems and processes will present a particular challenge. Besides the failure of air-conditioning systems and fans, the failure of electrically operated blinds or door and window systems can make it impossible to control the room temperature and result in overheating. This can lead to overheating and the associated dangers, not only in susceptible people such as children, those who are ill and the elderly (see also Section 4.2.2), but less sensitive people can also be negatively affected in everyday situations such as in the office or in trains braking down on the line. In the agricultural sector, a failure in the ventilation system in domestic animal barns can lead to overheating and therefore to livestock perishing.

Failure of cooling systems has a direct effect on people but, with a longer-lasting failure, also causes the spoilage of food and medicines which require cooling. Last but not least, a simultaneous power cut and heat wave can have consequences for the water sector. On the one hand a higher water demand may not be able to be met if the supply infrastructure fails and on the other there is a risk of drinking water becoming contaminated with pathogens due to higher temperatures and the water being stationary in the pipes.

V. Chapter

Vulnerability assessment of population and critical infrastructures
to heavy rainfall

Urban risks from heavy rainfall arise primarily from the collection of large amounts of water which, depending on the topography, can develop into flash floods due to an overload of natural or man-made drainage systems. Small streams can burst their banks and lead to flooding in a very short space of time. But even without running waters, heavy rainfall can present a hazard. Slopes and the depressions which lie below them but also depressions in relatively flat

terrain where the water cannot run off adequately are then particularly affected, (cf. e. g. Kron 2005 or Böhm et al. 2011).

A striking example of a heavy rainfall event with consequences both for CIs and the population is what is referred to as a "one hundred year rain event" which occurred over the whole of the eastern Ruhr district on Saturday 26.06.2008.

The one hundred year rain event in Dortmund, 26.06.2008

Precipitation during the event reached over 200 mm/m² locally (Cieminski und Brede 2008), with the southwest, west and south of Dortmund being worst affected. The city districts of Dorstfeld and Marten are particularly exposed to heavy rainfall due to their location in a depression and suffered the greatest damage. An important determining factor in connection with this was the land use. The high level of sealing in the urban conurbation, the removal of flood retention areas and the drains blocked by leaves and earth contributed to this natural hazard causing considerable damage (Allebrodt und Sponholz 2008).

Consequences for the population

Besides a few injuries, the greatest damage was to private property, public institutions and businesses. Cellars filled up, shops were up to 1.5 m under water and streets were flooded to a height of 1.8 m (dpa/lnw 12.08.2008). A secondary effect was that shop owners and their employees suffered a loss in income (dpa 2008). Businesses and house owners

in Marten suffered total losses of around 2 million € (Büchel 2008).

Consequences for critical infrastructures

The waste water systems were significantly overloaded. In one **pumping station** belonging to the Em-scherengenossenschaft, two of the three pumps broke down when they were submerged (Cieminski und Brede 2008). A **power cut** lasting 30-60 minutes affected 1,500 households. In the **transport sector**, rail lines were washed out, streets flooded and cars stuck (Linnhoff 2008). The **emergency services** were put under severe strain as, within six hours on the Saturday, 4,600 emergency calls were made to the fire brigade who carried out 810 operations up to the Sunday evening. Rescue services were given support by neighbouring districts who provided e. g. sand bags (dpa 2008).

What is significant in this connection is that the city had no previous experience with large heavy rainfall events (Grünewald 2009).

A heavy rainfall event like the one in Dortmund can function as a reference event for the methods presented here. Although these were developed in cooperation with the City of Wuppertal, to date there has been no damage there which illustrates the potential damage from heavy rainfall as clearly as the example cited. It should be clearly stated that, besides the mentioned flooding, heavy rainfall can also trigger

what are known as flash floods having potentially different and even additional effects. It is therefore important to distinguish these events with their specific consequences. Heavy rainfall is initially defined as large amounts of precipitation per unit of time. The DWD gives warnings of heavy rainfall in 2 stages (when it is anticipated that the following threshold values will be exceeded):

- Quantity of rain ≥ 10 mm / 1 hour or ≥ 20 mm / 6 hours (significant weather warning)
- Quantity of rain ≥ 25 mm / 1 hour or ≥ 35 mm / 6 hours (severe weather warning)

Heavy rainfall can quickly lead to rising water levels and/or flooding, frequently accompanied by soil erosion (cf. DWD 2013a). A number of factors are critical for the effects of heavy rainfall, amongst these particularly the local topography. However, the kind of soil and percentage of sealed area and the type of land use are also important characteristics which partly determine the occurrence of local floods (cf. e. g. Bartels 1997, Naef et al 1998, Perry 2000, Kelsch et al. 2001; Barredo 2007). In contrast to "simple" pluvial floods in flat terrain, flash floods are characterized by their highly dynamic nature. Water levels can rise dramatically in a very short time and wash away people and buildings. For example, in 1996, 87 people died in a flash flood in Biesca in Spain (cf. Barredo 2007). Both, heavy rainfall and flash floods can also cause soil erosion and trigger landslides or mudslides. A large number of the events which have already occurred in Germany are recorded in the URBAS database (2011)²⁹.

A number of challenges arise when it comes to taking preventative measures against the effects of heavy rainfall and flash floods. Heavy rainfall events occur infrequently and are very local in extent (see e. g. Gaume et al. 2004 or Montz and Grunfest 2002), so that there is usually little awareness of or preparation for such natural events. The willingness to make investments is often limited due to the low likelihood of the event and the lack of experience with this natural hazard. This tendency is reinforced by the short response times which e. g. municipal authorities have to take measures in response to early warnings (Montz and Grunfest 2002). Lastly, a further challenge in dealing with heavy rainfall events is the limitations of

the observation stations and the models whose weather predictions about heavy rainfall events are fraught with uncertainty (Creutin et al. 2009 or Marchi et al. 2010). For these reasons it is particularly important to analyse possible vulnerabilities in advance and to reduce these by targeted measures.

For the purposes of the guideline, the question therefore arises as to the form in which these requirements can be satisfied and a distinction made between *flooding from heavy rainfall* (pluvial floods) and *flash floods* – particularly against the background of the diversity of the municipalities in which there are some larger gradients but in most cases scarcely any differences in height, so that flash flooding is less likely to arise and heavy rainfall generally results in local flooding. For this reason the method developed relates to flooding caused by heavy rainfall and in the first instance ignores dynamic aspects which are of crucial importance in the case of flash floods. This view is also due to the fact that, although in principle hydrological modelling e. g. of small river courses can be used to assess the effects of heavy rainfall, these methods are very time-consuming and therefore cost intensive. If it is assumed that heavy rainfall can lead to flash floods by direct run-off (e. g. through streets) and the entire area of the municipality can therefore be affected, it is clear that the corresponding observations would exceed the resources of most municipalities. The method presented here allows for the identification of local hot spots and thus the determination of zones which can be further analysed using dynamic modelling. As there has to date been almost no awareness of the risk of heavy rainfall in many municipalities, the methods developed should serve as a first approach to taking account of this topic. However, in municipalities with steep slopes the possible occurrence of destructive flash floods should be considered and precautionary plans put in place.

²⁹ http://www.urbanesturzfluten.de/ereignisdb/ereignisse/ereignisse_view.

5.1 Methods for assessing depressions

In the method presented here, local depressions were identified in which water can collect in the case of a heavy rainfall event, as will be explained in this chapter. The result was used as a basis for the assessment of the exposure of the population (residential buildings) and CIs which may be subject to local flooding. In order to allow for the complexity of heavy rainfall events and the flash floods which may arise from these, it is also recommended to include the flow paths which belong to the depression. These can be added in the form of polygon lines in geographic information systems and thus also be incorporated into the assessment of exposure. The same applies to the courses of streams and rivers. Moreover, the slope gradient can be used as indicator for regions with high run-off velocities.

In the sample municipality of Wuppertal, a large proportion of the streams are piped underground. This results in the special problem that, at the transitions from open to piped waterways in particular, flooding

arises because the pipe openings can get blocked by branches, leaves etc. carried by the water body. Local depressions are present at these locations which are included in the analyses as inundation areas. The sewers and corresponding drains are not included in the analyses for taking account of *worst case* scenarios which can arise due to their overloading or blocking.

Based on the analysis of other vulnerability parameters, targeted measures, for example as part of the municipal drainage system (e. g. prioritising the updating of general drainage planning for some locations), strengthening of certain buildings and components and the installation of engineering reconstruction works such as flood retention basins can be carried out. Additionally, detailed hydrological analyses which also include e. g. dynamic parameters of importance for flash floods could be carried out in specific areas which have been identified as vulnerability hot spots.

5.1.1 Calculating depressions using a digital height model

The first requirement for identifying the topographical depressions described is to develop a high resolution digital elevation model (DEM). Using the laser scan data with the highest possible density of points (DGM_1L, for NRW: 1-4 pts./m²) provided by each

Land, regular grid DEMs can be interpolated so that a 25 x 25 cm grid can be spread over the irregular laser scan data points (see Figure 16). For grid cells which contain a laser scan data point, the height of the data point was transferred approximately to the grid cell.

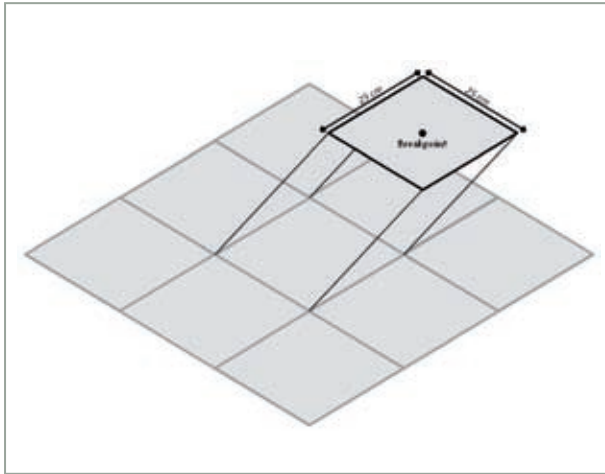


Figure 16: Determination of height values by interpolation using laser scan data points

Source: Ingenieurbüro Reinhard Beck GmbH & Co. KG 2012.

The complete model for the municipality is obtained from two partial grid DEMs using this methodology. The terrain without vegetation or buildings is created using what are known as last pulse ground data points. The roof surfaces of the buildings are modelled from the last-pulse non-ground data points. The combination of the two partial grids produces the final grid DEM for the city. Due to the permeability of vegetation and in order to avoid the output of non-plausible depressions, the vegetation was not shown in the height model. Depressions could be recognised by identifying local low points and taking account of the surrounding terrain. In the worst case scenario these would be filled with water to their overflow point.

5.1.2 Assumptions about the terrain surface for calculating depressions

Precision of depressions

Basically, digital height models contain slight inaccuracies. The data are obtained using a laser scanner fixed to an aeroplane. The sensor sends out laser pulses which are reflected from the surface and absorbed again by the scanner. The exact position of each reflected point can be determined using the tra-

vel time of the pulse. If digital height models are checked using terrestrial measuring techniques, then the values of the height models deviate by up to 20 cm. These inaccuracies are therefore reflected in the digital terrain model and must be taken into account when analysing the depressions.

Street and railway embankments and bridges

The mapping of culverts, underpasses, bridges and other flow opportunities is essential for identifying the depressions. For culverts in street or railway embankments it is usually the top of the embankment which is shown in the elevation model using the last pulse ground data points. The consequence of

this is that a depression is identified in front of the embankment which in reality does not arise due to the culvert. As a consequence, the embankment in the elevation model has to be cut so that no reverse gradient appears at this point. The same applies to bridges.

Adding houses

Buildings are added to the model in a separate step.

Revising the data set

Closed internal courtyards and some roofs are initially shown as depressions by this method. However, these can be removed from the data set by an automated GIS request. Figure 17 shows the depressions

in an initial version i. e. with internal courtyards and roofs section of the City of Wuppertal. For further processing, the revised data set was used.

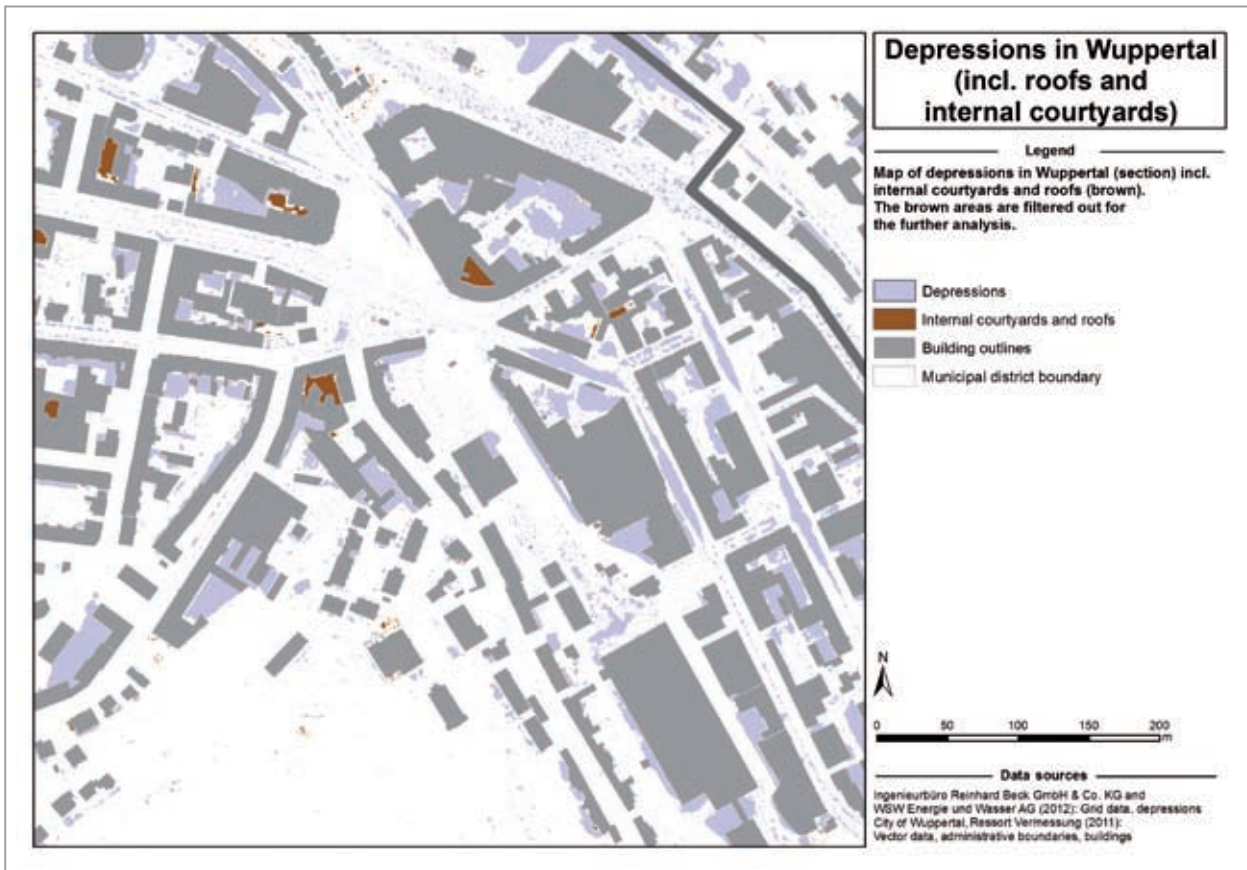


Figure 17: Map of depressions in Wuppertal incl. roofs and internal courtyards

Source: own figure based on data from WSW Energie und Wasser AG, the engineering consultant Reinhard Beck GmbH & Co. KG and the City of Wuppertal.

Drainage

In the depression data set which was also used for further studies, stream piping and road drains into the sewerage system were ignored in order to produce a *worst case* scenario. This enables the maximum flood-

ding depths to be looked at in further assessments. If the municipality wants to include the relevant drains, this can be done by *intersecting* the relevant flow paths in the model.

Identification of depressions at risk of flooding

To date there has not been any statutory basis for calculating and identifying areas affected by heavy rainfall. The EU Directive 2007/60/EC on the assessment and management of flood risks and the corresponding regulations in the German Water Management Act (Wasserhaushaltsgesetz, WHG) (para. 72-81) relate explicitly to "floods". Under the terms of the Directive this means flooding from rivers, mountain streams, intermittent running waters in the Mediterranean region and the encroachment of seawater in coastal areas. However, the direct effects of heavy rainfall and flooding from waste water systems do not come under this. While para. 74 I WHG stipulates that risk and hazard maps must be compiled for floods, there are no compa-

nable regulations for heavy rainfall and the run-off associated when not connected to running waters.

For these reasons the local authority needs to check to what extent data on exposure to local flooding areas caused by heavy rainfall can be made accessible to the public, taking account of data protection and insurance aspects. It remains largely unclear as to whether and to what extent geographical data and data on real estate fall under the data protection legislation (cf. e. g. Weichert 2007). One option for solving the data protection problem could be the provision of information on depressions upon request by the concerned property owner only.

5.1.3 Taking account of depression depths

Besides mapping depressions as risk areas for local flooding, these can also be assigned depth values which could be of particular relevance for the further assessment of potential vulnerability of the popu-

lation and infrastructure components. As Figure 18 shows, this was divided by way of example into four categories between $< 20\text{ cm}$ and $> 100\text{ cm}$.



Figure 18: Map of depression depths in a sample section of the City of Wuppertal

Source: own figure based on data from WSW Energie und Wasser AG, the engineering consultant Ingenieurbüro Reinhard Beck GmbH & Co. KG and the City of Wuppertal.

A classification of depression depths can provide a basis for excluding particular depressions. In Wuppertal, for example, as a result of a round table discussion, it was agreed that those depressions whose surface was less than 1 m² could be neglected³⁰. It is important to have a definition of the depressions to be neglected in order to limit the exposure of buildings and CIs by means of filters (buffers around the

buildings). As will be shown below, this enables the identification of buildings (e. g. socio-economic service infrastructures) or components which should be studied in more detail as a priority. A respective limitation allows for the in-depth analysis of individual cases which is necessary in order to make statements about the drainage of depressions and the susceptibility of the infrastructure.

³⁰ In principle even small depressions can have a damaging potential if these drain directly into a basement shaft, for example, and keep on filling up in the course of a heavy rainfall event. Nevertheless, in the interests of the operationalisability of exposure, this exclusion procedure was selected for the guideline. The damaging potential of depressions can also be given added plausibility by the inclusion of catchment areas.

5.1.4 Costs

A local authority can have the steps presented so far carried out by an engineering consultant who has access to the specialist knowledge and the computing capacity for what can be very substantial computing processes. To allow for an initial assessment of the

resulting costs, approximate figures are presented in Table 9. The area of the municipality for which the depressions have to be calculated is the critical factor for the costs.

Table 9: Approximate costs for the calculation of depressions in relation to the area of the municipality

Size of area [km ²]	Approximate costs [€] ³¹
10	3.000 – 4.000
100	5.000 – 6.000
500	12.000 – 14.000

Source: Ingenieurbüro Reinhard Beck GmbH & Co. KG 2012.

The revision of the data set for bridges and internal courtyards already mentioned above and the combination of point data into polygons, i. e. areas, produces additional costs which amount to around €4,000 for medium-sized municipalities. The conversion

into area-related data is nevertheless useful in order to be able to filter out depressions beyond specific threshold areas and therefore only look at *relevant* depressions within the city.

The costs of approx. €10,000 - 20,000 may appear high at first glance. However, as part of the cost-benefit analysis, account should be taken of possi-

bilities for structural protection such as storm water basins which can be reduced or implemented in a more targeted manner.

³¹ Non-binding cost assessment as of 2012.

5.2 Vulnerability of the population to heavy rainfall

Figure 19 shows the topics, indicators and expanded criteria of relevance for the population³², which were identified on the basis of intensive research of the available literature, as well as from expert interviews. Indicators are very important for preventative planning as they can identify local *hot spots* by means of a two-dimensional presentation. They can for example be taken into account in urban planning processes or in operational planning by the emergency services. However, when it comes to heavy rainfall events, the use of indicators for a spatially differentiated presentation of the vulnerability of private households proves to be particularly difficult. This is due both, to the very localised spatial impact and to the lack of relevant spatially differentiated data. For example, buildings where a backflow prevention device has been installed are not recorded in the municipal statistics. The relevant information could only be collected on a large scale by e. g. (costly) household surveys. The localised impact is due on the one hand to the mostly small-scale occurrence of heavy rainfall events, something which is difficult to predict (regarding the prediction of heavy rainfall see also Creutin et al. 2009 or Marchi et al. 2010). In addition, the topographical features (especially depressions, slope gradient and land-use) which determine the effects of heavy rainfall also vary greatly at a small scale. The point nature of the distribution of exposure may decrease the expressiveness of a vulnerability value e. g. on city district level. However, it allows for the

examination of individual cases and therefore the identification of the exposure of social institutions which cater for particularly vulnerable people (e. g. old people's homes, hospitals, nurseries) (see Section 5.3.1). The flooding of depressions will predominantly lead to structural damages on buildings, e. g. by filling up rooms in the basement (cf. URBAS-database). Depending on the functions of the basement, e. g. nurseries, schools or hospitals, already comparatively small amounts of water can lead to high damages. Partly, common rooms or surgery rooms are situated in the basement so that relatively small amounts of water can cause considerable damages already. At the same time heavy rainfall can also, subject to local conditions, trigger flash floods. In their context human physical vulnerability plays an important role (Jonkman 2005).

The UNU-EHS household surveys were only able to show a few significant correlations between important factors of vulnerability (e. g. risk perception, level of information) and data normally available in local authority statistics. For these reasons, a vulnerability assessment based on the indicators presented here should be complemented by the expanded criteria (such as the protection of houses from water penetration using backflow flaps). As collecting the relevant data can be very resource intensive, one option is to carry out the survey only in the relevant areas identified by the exposure assessment.

³² For the distinction between "indicators" and "expanded criteria" see Section 2.4

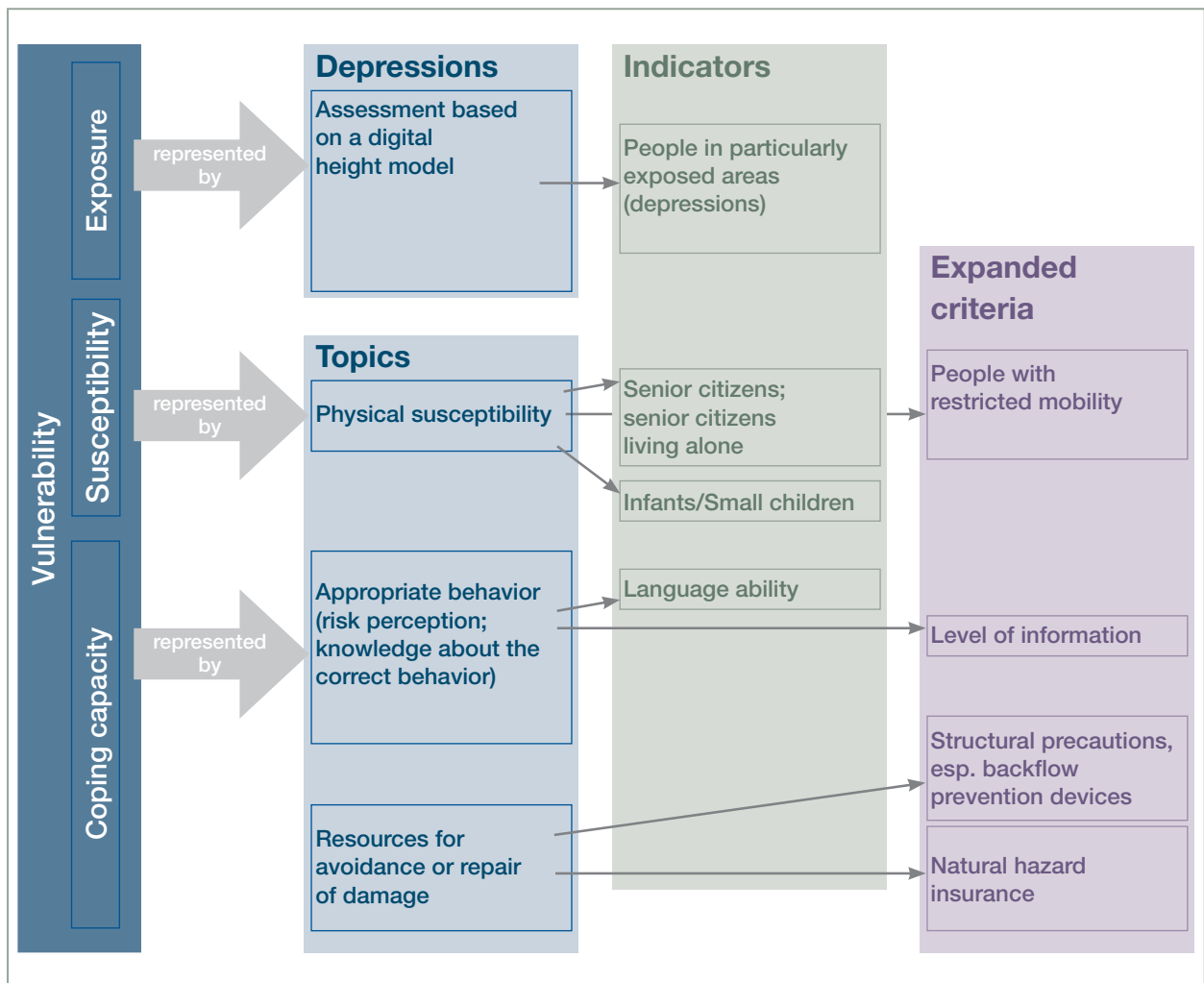


Figure 19: Topics, indicators and criteria for assessing the vulnerability of the population to heavy rainfall events

Source: own figure.

The topic areas shown in Figure 19 overlap to a large extent with the indicators and expanded criteria which were identified for the natural hazard heat wave (see Section 4.2). This can be explained by the fact that particularly important factors such as physical susceptibility basically determine people's vulnerability and can partly be considered as independent of the natural hazard (cf. e. g. ICSU-LAC 2010, Schneiderbauer and Ehrlich 2006). Nevertheless, the aspects which make the indicators and criteria relevant are (partially) specific to heavy rainfall are discussed separately for each indicator and criterion in what follows. Considering the physical susceptibility, for example, in the context of heavy rainfall it is people's mobility which is of particular importance and deter-

mines the ability to carry out preventive measures. For most events of small magnitude where mostly little structural damages occur, the physical susceptibility is of minor relevance. However, it increases in significance if heavy rainfall causes larger inundations or a flash floods with high flow velocities.

For coping capacity, the two topics specific to heavy rainfall appropriate behaviour (risk awareness/knowledge about correct behaviour) and resources for avoidance or repair of damage (structural precautions and financial insurance against damage from heavy rainfall/flash floods) were identified. These are of particular relevance in the context of heavy rainfall whilst they are hardly for heat waves.

5.2.1 Exposure

Exposure is determined by intersecting data on residential buildings with data on the location, size, and depth of depressions. In the following, consideration

of individual cases as well as detection of exposure on city district level is introduced and discussed.

Indicator: Exposure – population in areas that are specifically exposed to heavy rainfall (depressions)	
Recording unit: single buildings (consideration of individual cases) or e. g. city districts	Measurement unit: consideration of individual cases or percentage of residential buildings that border on a depression (e. g. with a depth of at least 21 cm and a surface of at least 1 m ²)
<p>Relevance: The exposure, here of residential buildings that border on a depression, is a highly relevant component of vulnerability. The identification of residential buildings which might be affected from invading water during heavy rainfall events is basic information for measures for the protection against impacts of heavy rainfall. With this information, focused measures can be implemented for the protection against invading water, as well as to better cope with the impacts of flooding due to heavy rainfall.</p>	
<p>Technical notes:</p> <p>For the exposure towards heavy rainfall events basically several factors play a role. Here, especially the location of buildings and their bordering on (a) depression(s) have been considered. In order to identify the respective exposure, depression data (see chapter 5.1) are intersected with data on buildings, enabling an analysis on building or housing block level. Hereby, the often spatially very limited occurrence of this natural event is also taken into account.</p> <p>To provide an overview on the whole area of the municipality, e. g. on city district level, the data on buildings and their exposure can be aggregated.</p> <p>If further information, such as slopes, flow paths, or stream courses is available, the preciseness of the results can be enhanced (see chapter 5.1).</p> <p>The estimation of exposure refers to residential buildings. Offices and factories are disregarded, to avoid a biased representation of the exposure due to the inclusion of e. g. storage buildings. Further, in the following examinations of susceptibility and coping capacity, socioeconomic data is used, which is assigned to places of residence. However, it would be reasonable, besides the resident population (<i>population at night time</i>), to also survey the people with an exposed working place (<i>population at daytime</i>) and to consider them in the exposure assessment.</p>	
<p>Source of data: Land registry or land surveying office; concerning data sources for estimating depressions see chapter 5.1.</p>	

It is basically advisable to analyse exposure based on consideration of individual cases. This is the only way to check where the deepest point of the small-scale depressions lies and whether there are drains, underground car parks or basements into which the water would flow (see LANUV NRW 2013). In order to conduct the respective analysis, *buffer zones* were

established around the buildings which represent an area around the buildings which is needed to determine the exposure. A building is considered as exposed if a depression of at least 20 cm of depth and 1 m² area is located in the buffer zone (1 m) (see figure 20).



Figure 20: Assessment of exposed residential buildings illustrated by a section of the City of Wuppertal

Source: own figure based on data from WSW Energie und Wasser AG, the engineering consultant Reinhard Beck GmbH & Co. KG and the City of Wuppertal.

The exposure analysis of buildings leads – subject to the selected values for depression depth and surface area - to a reduction of those buildings which have

to be analysed in more detail on an individual case base (see table 10).

Table 10: Share of exposed buildings in Wuppertal in relation to different depression depths

	all depression depths (surface area above 1m ²)	depressions from 21 cm depth (surface area above 1m ²)	depressions from 101 cm depth (surface area above 1m ²)
Buffer around building (in m)	1		
Number of residential buildings	41.544	18.584	3.729
Percentage of exposed buildings	80 %	36 %	7 %

Source: own figure based on data from the City of Wuppertal.

In addition to an individual case base analysis, the examination of exposure patterns on a higher scale, e. g. on a district level allows for the comparison of different areas of the municipality and the depiction

of heterogeneities while reducing the level of detail. Figure 21 therefore shows the share of exposed buildings per city district.

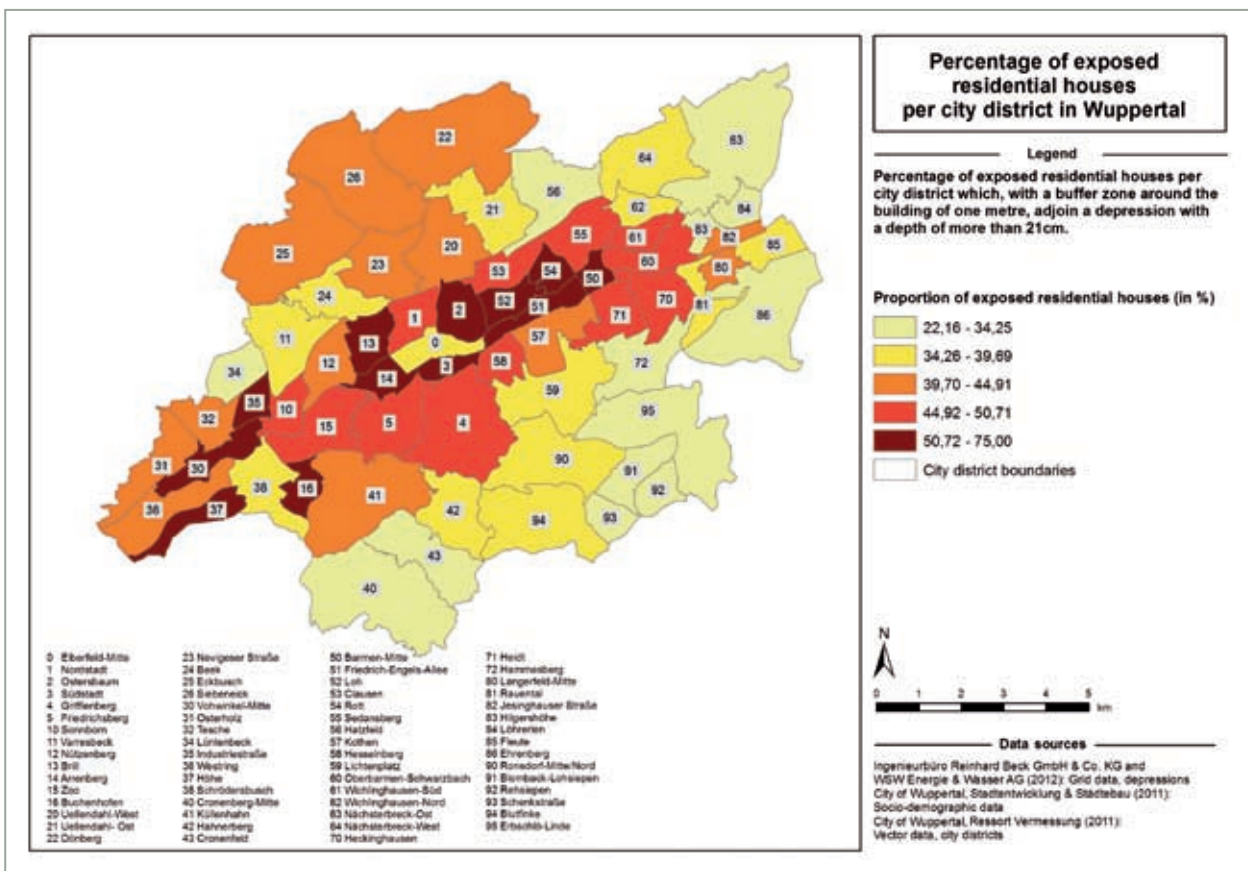


Figure 21: Exposure of the population to heavy rainfall in the City of Wuppertal. Sample illustration of a depression depth greater than 21 cm at city district level

Source: own figure based on data from the City of Wuppertal.

Excursus: Consideration of land cover and slope for the analysis of exposure

Since heavy rainfall events can – subject to a variety of factors such as intensity and duration of the event, local topography and land use patterns – trigger flash floods (see e. g. Bartels 1997, Naef et al 1998, Perry 2000, Kelsch et al. 2001; Barredo 2007), it is reasonable to consider these factors in

the analysis of exposure patterns in addition to the depressions if feasible. Land use or slope data can be acquired via remote sensing methodologies (for more details see the KIBEX final report) and can also be mapped as figures 22 and 23 show.

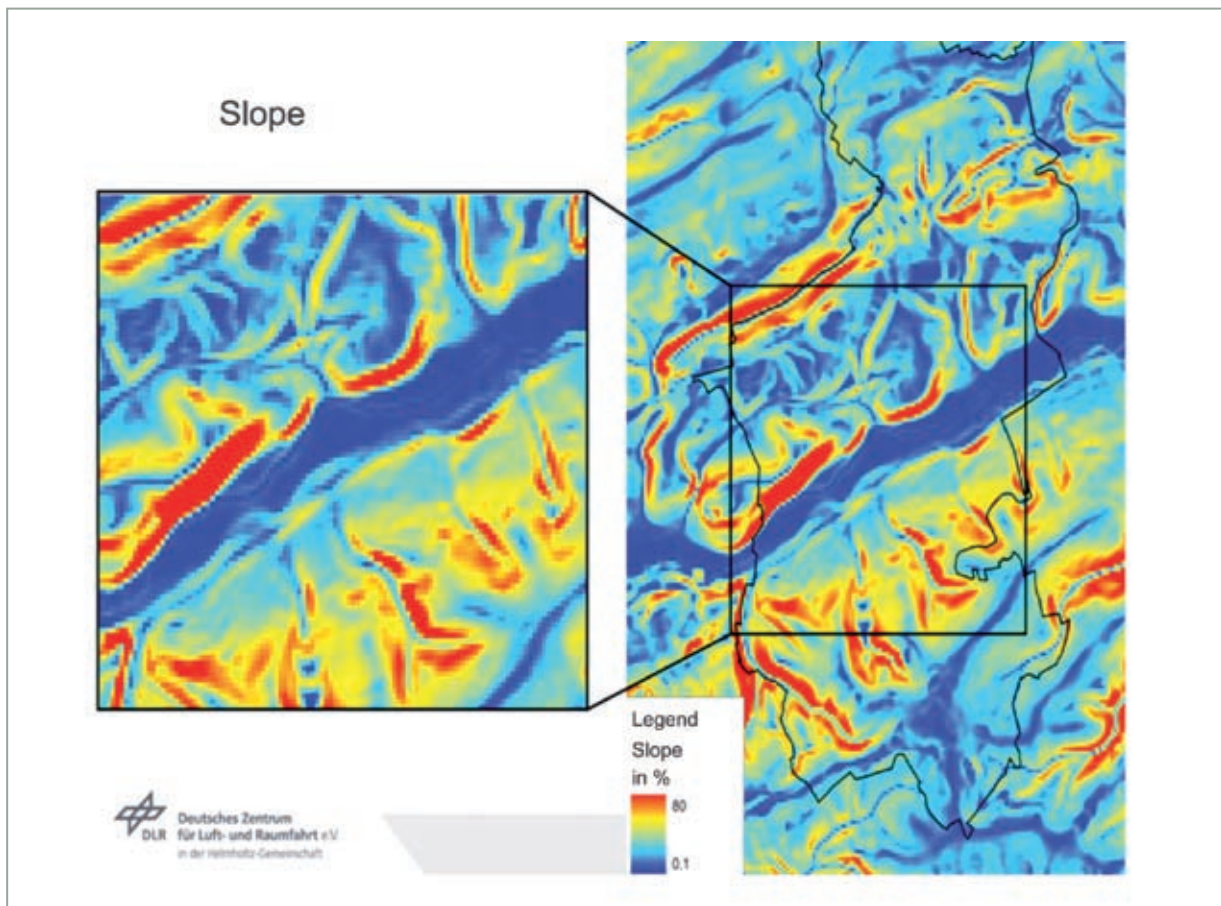


Figure 22: Slope mapping based on a digital land model

Source: Klein 2011.

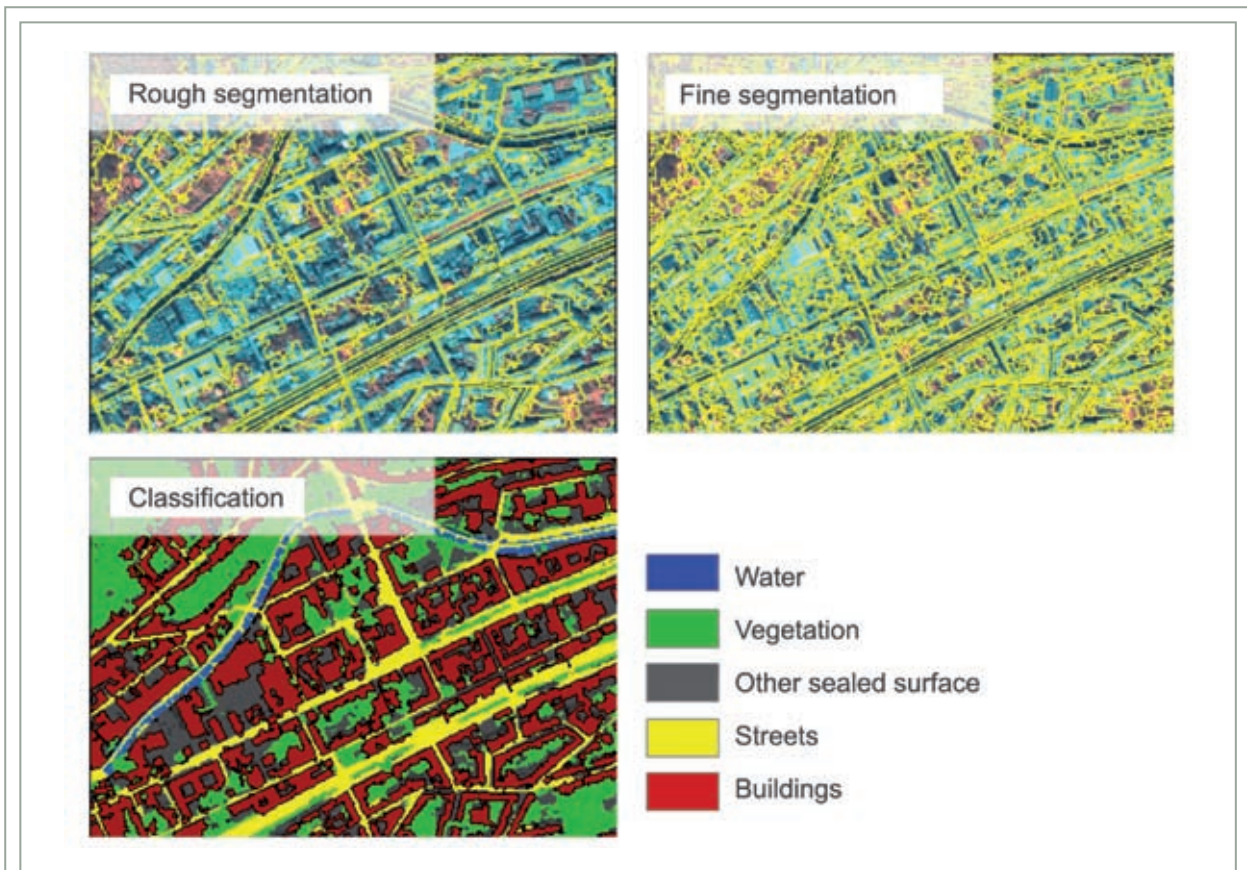


Figure 23: Object based hierarchic land cover classification

Source: Taubenböck et al. 2011.

Concrete and quantifiable correlations between slope or land cover classification and exposure patterns in terms of flow velocities could however not

be determined within the scope of the project and are thus not integrated into the outlined methodology.

Potential measures at municipal area level for the reduction of exposure towards heavy rainfall:

In order to reduce the exposure of the population to heavy rainfall, the options available to the municipality lie mainly in structural and urban planning measures to encourage water drainage, as shown for example in the "Handbuch Stadtklima" (MUNLV 2010).

These include e. g. the removal of sealed surfaces and/or the use of water permeable paved surfaces or the designation of intermediate storage areas for rainwater (e. g. on public open spaces such as sports grounds or car parks) and emergency waterways

(e. g. individual streets with raised kerbs). Options for safeguarding appropriate areas comprise designations in the development plan, e. g. a non-constructional use, or the designation of areas for waste and waste water disposal including the retention and infiltration of rainwater in accordance with para. 9 (1) No. 14 of the German Federal Building Code (BauGB) (MUNLV 2010). The assessment can also be used for prioritising specific areas for updating the general drainage planning.

5.2.2 Susceptibility

As already mentioned, the physical susceptibility to heavy rainfall is particularly relevant during major events in which people are directly exposed to danger. In extreme cases such as the flash flood in southern France in 2002, differences in how much people are affected as a result of varying physical susceptibility can however become blurred again, as in a case of this kind it is mainly people on the street who are affected who are generally healthy and fundamentally of low susceptibility (Ruin et al. 2008). At the same time physical susceptibility plays a part not only in terms of the ability to physically withstand the flood event. Rather, it is additional factors that are relevant, such as the ability to take preventative measures and for the protection of personal property.

Topic: physical susceptibility

While in the context of heat waves and in the topic area of physical susceptibility mainly direct impacts on people's health are in the foreground, people's mobility is particularly relevant for the physical susceptibility of the population to heavy rainfall. This applies e. g. to the ability to take measures or with regards to necessary (and possible) evacuation practices in extreme situations (cf. Kaźmierczak and Cavan 2011; Birkmann et al. 2010b; Cutter et al. 2000). Furthermore, elderly and small children are more susceptible to suffer from health impacts (Kaźmierczak and Cavan 2011, Cutter et al. 2000). Therefore, seni-

The topic of *physical susceptibility* with the indicators

- *Senior citizens; senior citizens living alone*
- *Infants/small children*

and the expanded criterion

- *People with restricted mobility*

(see also Figure 19) will be explained in what follows.

or citizens (*living alone*) and *infants/small children* are used as indicators (similarly to the topic of heat waves, whereas the reasons for selecting these indicators, as explained, are slightly different). Figures 24 and 25 show the indicators using Wuppertal as an example. It can be seen on these maps that in the districts no. 50 (Barmen-Mitte) or no. 70 (Heckinghausen) there is a relatively high percentage both of senior citizens living alone and of infants/small children. Thus, an increased susceptibility is expected in this regard.

Indicator: Senior citizens (living alone)

Recording unit: e. g. city district

Measurement unit: Percentage of senior citizens (65 and older) in the population living alone

Relevance: Because elderly people might be restrictedly mobile and therefore be more dependent on help, particularly if rapid movement is necessary (cf. e. g. Birkmann et al. 2010a, Wilhelmi and Morss 2012). In addition, they may have difficulties to protect their property or take other preventative measures (Clark et al. 1998 or Kaźmierczak and Cavan 2011). Furthermore, they are more susceptible with respect to health e. g. towards injuries or contamination of water (Kaźmierczak and Cavan 2011; Cutter et al. 2000). A lack of direct support by additional members of the household can further increase the vulnerability of senior citizens living alone.

Technical notes:

It must be noted when interpreting the indicator that it includes people living in e. g. elderly homes whose vulnerability differs from that of people in private households due to the care provided. If there are data available on the predicted changes in the population according to age groups, it is worthwhile integrating these data into the assessment of vulnerability as additional information in order to be able to consider relevant information in the planning process.

Source of data: Local authority department of statistics

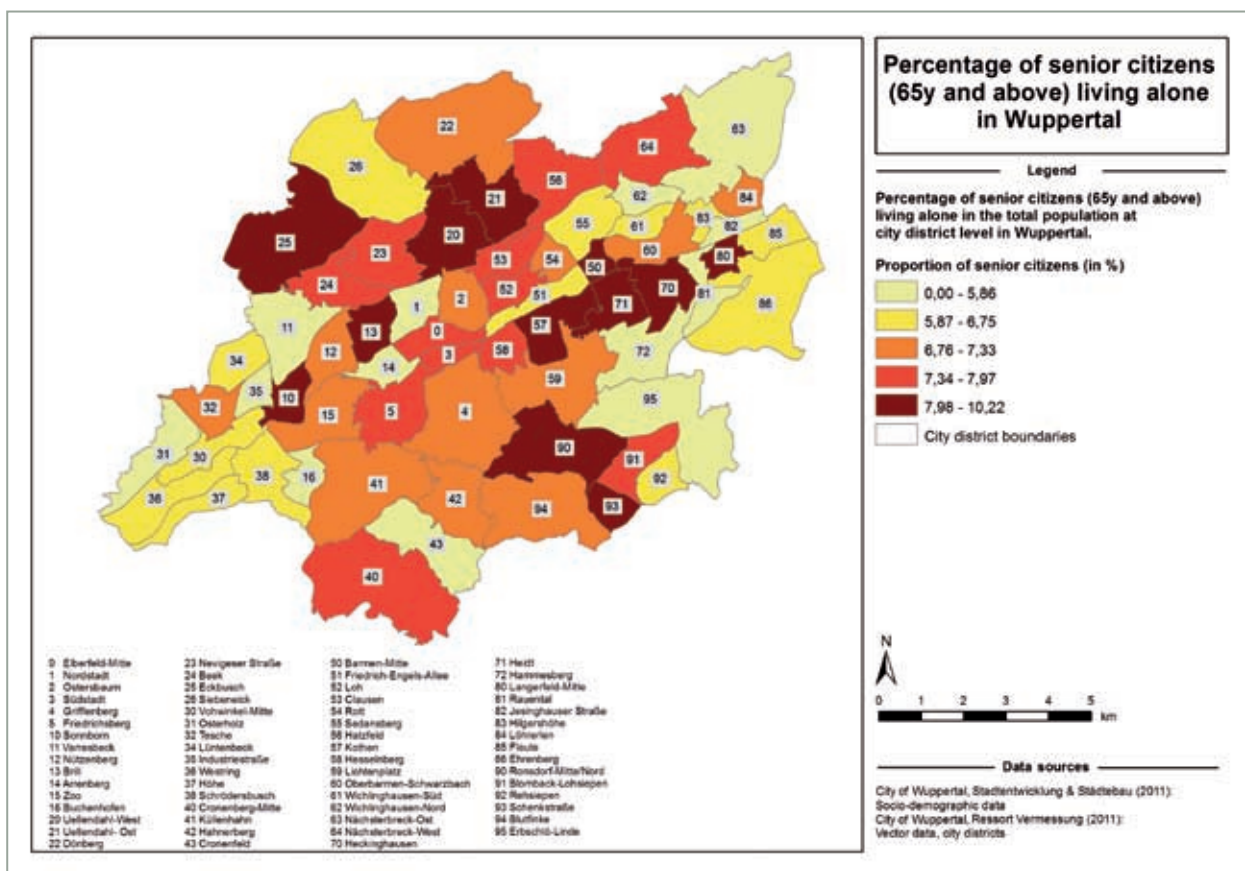


Figure 24: People over 65 living alone in the City of Wuppertal at city district level

Source: own figure based on data from the City of Wuppertal.

Indicator: Infants/Small children

Recording unit: e. g. city district

Measurement unit: Percentage of infants/small children (aged 0-4 years) in the population

Relevance: Small children are dependent on help and at risk even from floods of minor depth. In addition, the speed with which it may be necessary to leave the flat/building can be of significant importance and this is often slower in households with small children (Birkmann et al. 2010b, Cutter et al. 2000). Furthermore, they are more susceptible with respect to health e. g. towards injuries or contamination of water (Kaźmierczak and Cavan 2011, Cutter et al. 2000).

Technical notes:

If the data contains an estimate of the change in the population by age groups at a small-scale (e. g. city district), it is useful to integrate this data in the vulnerability assessment in order to be able to consider relevant information in the planning process.

Source of data: Local authority department of statistics

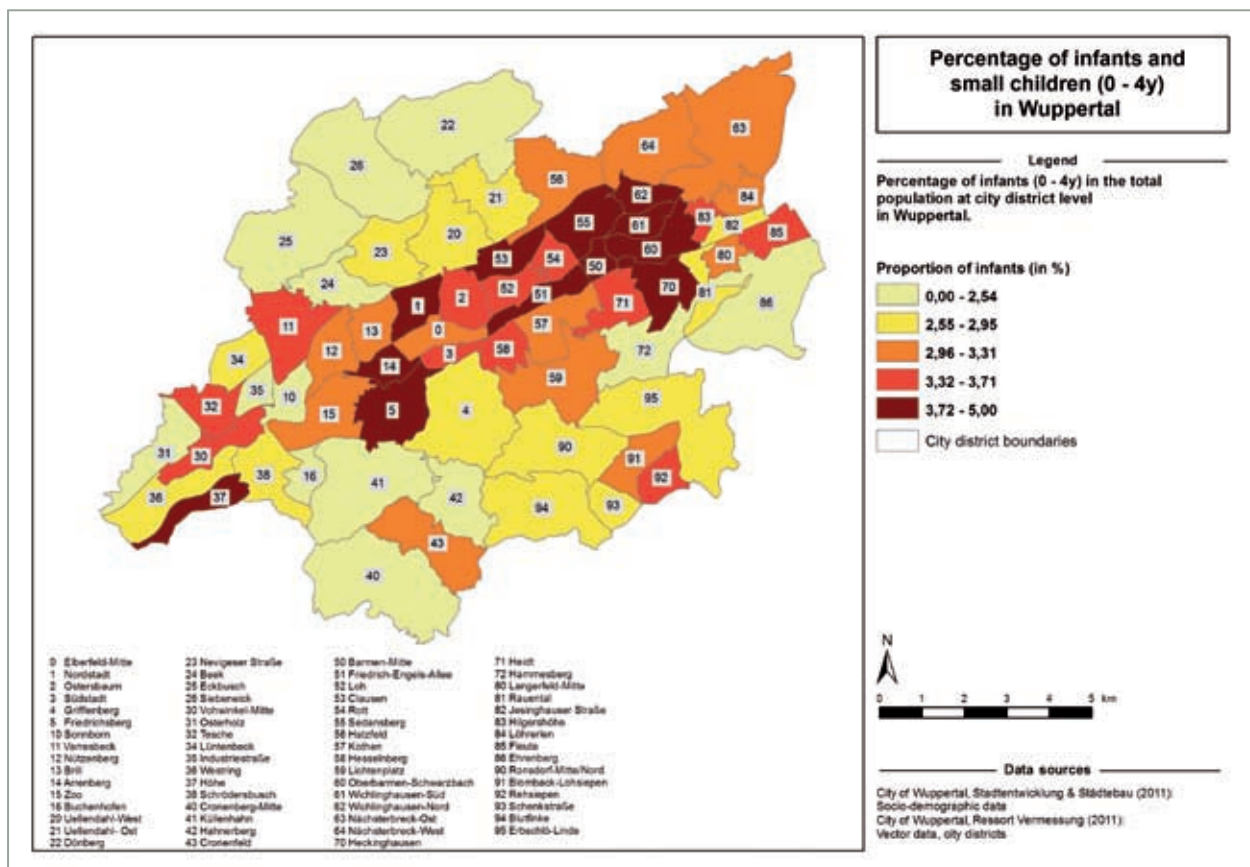


Figure 25: Percentage of infants and small children (0 - 4y) in Wuppertal

Source: own figure based on data from the City of Wuppertal.

Criterion: People with restricted mobility

Relevance: People with restricted mobility are particularly at risk if large amounts of water arrive rapidly and unexpectedly and it is necessary to leave the flat/building. In this case an increased requirement for assistance is to be expected.

The data (e. g. on "impaired mobility") are not always available but are sometimes held by the cities (e. g. based on municipal resident surveys). Due to the particular susceptibility of the specified groups, hot spots should be identified where large numbers of mobility impaired people live (see Section 5.3.1), for example elderly and nursing homes, hospitals or institutions which care for people with disabilities.

Potential measures at municipal area level for the topic of physical susceptibility:

It is often almost impossible to give early warning of heavy rainfall events because weather warnings are not detailed enough to provide information about weather events which occur at a very local level such as heavy rainfall. They are frequently incorrect, so that local authority decision makers only pay very limited heed to existing warnings of potentially heavy rainfall.

Study of the spatial distribution of physically susceptible groups can serve as an initial starting point for further studies of individual cases, in other words a

more accurate study of the exposure and further aspects of vulnerability in selected areas of the city. It is also possible to make appropriate plans for rescue measures based on information on areas with a particularly high demand for care assistants, especially for institutions such as elderly homes, nurseries etc. The care ratio, i. e. the number of carers per person and also the type of care is also of relevance for the need for external assistance, as this has an influence on whether and how much additional help will be required.

5.2.3 Coping capacity

The following indicators and expanded criteria are used and described for the coping capacity of the population to heavy rainfall (see also Figure 19):

For the topic of *appropriate behaviour (risk awareness; knowledge about correct behaviour)* the indicator

- *Language ability*

and the expanded criterion

- *Level of information;*

under the topic *resources for avoidance or repair of damage*, the expanded criteria

- *Structural precautions, esp. backflow prevention devices*
- *Natural hazard insurance.*

Topic: Appropriate behaviour (risk awareness; knowledge about correct behaviour)

While language ability is of relevance in the context of heat waves both for recommendations on preventative behaviour and for early warnings, in the context of heavy rainfall it is important particularly for preventative information as early warnings to heavy rainfall still pose a challenge. Because the relevant

information material is usually only available in German, people with little knowledge of the German language have only a limited possibility of obtaining the relevant information and being able to take preventative actions.

Indicator: Language ability – initial approximation: percentage of foreign fellow citizens

Recording unit: City district

Measurement unit: Percentage of foreign fellow citizens (= people without German nationality) in the population

Relevance: Often information on preparing for an event and during the event itself is only communicated in the German language which can be a disadvantage for foreign fellow citizens. Sections of the population with poorer knowledge of the German language then have less chance of preparing themselves and of responding in accordance with advice during the incident (cf. e. g. Geenen 2010; Wilhelmi and Morss 2012).

Although large numbers of people of non-German nationality have good German language ability and conversely some people of German nationality speak very little German, there is a strong correlation between nationality and German language ability³³. As direct data on language ability is not generally available, this correlation can be used as a first approximation in order to e. g. identify city districts where information on heavy rainfall might be required in foreign languages.

Technical notes:

Besides language, other correlations between foreign fellow citizens and vulnerability can sometimes be identified, for example in relation to economic resources, cultural contexts of meaning or family structures (cf. e. g. Geenen 2010; Medina-Ramón et al. 2006; Schwartz 2005). Within the framework of the KIBEX project it has not been possible to prove these correlations adequately and they have therefore not been given further consideration for the set of indicators.

Source of data: Local authority department of statistics

Figure 26 shows the percentage of foreign fellow citizen in Wuppertal at the city district level. The very high level of variation (from below 8% to over 55%) points to differences in coping capacity due to pos-

sible language barriers. Providing information on prevention in foreign languages in this context was endorsed in the expert interviews.

³³ In the UNU-EHS household surveys, the percentage of foreign fellow citizens who can speak at least moderately good German (on a scale of 1 to 5, 3 = moderate), comes to 38.7% in total. Similar figures were found in the German Socio-Economic Panel (SOEP) – according to this, in 1999 35% of foreign fellow citizens could not speak good German. (http://www.diw.de/deutsch/wb_24/01_deutsche_sprachfaehigkeit_und_umgangssprache_von_zuwanderern/30819.html, 28.02.13).

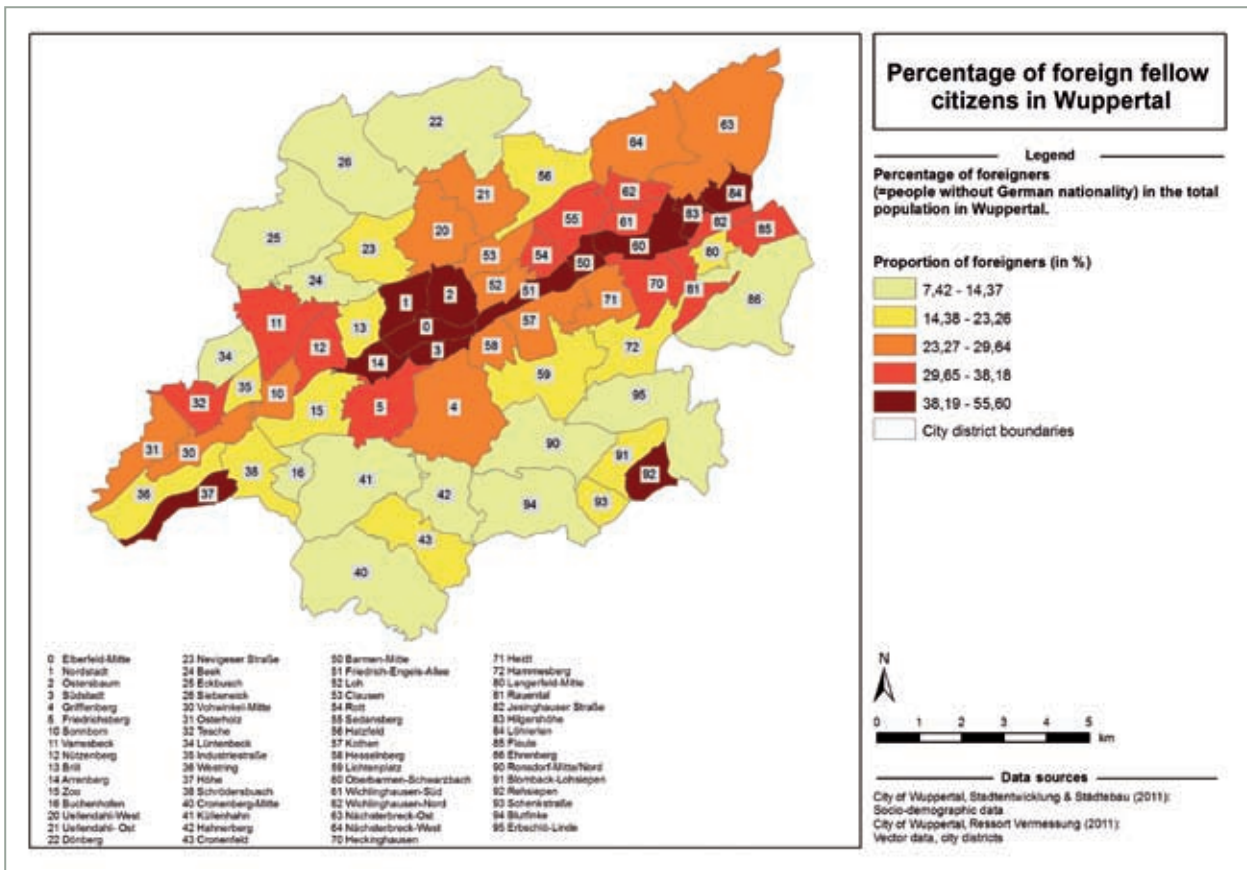


Figure 26: Percentage of foreign fellow citizen in Wuppertal at a district level

Source: own figure based on data from the City of Wuppertal.

Criterion: Level of information in dealing with heavy rainfall – level of education

Relevance: The access to information is considered as an important factor for the assessment of vulnerability towards a natural hazard (Cutter et al. 2003; Kaźmierczak and Cavan 2001).

As in the context of heat waves, the UNU-EHS household surveys could show that people with a higher level of education would be more likely to take measures which would enable them to deal better with the effects of heavy rainfall. They also tend to assume that extreme events increase in the future. The level of education (both the type of school-leaving qualification and the type of highest vocational qualification) was strongly correlated with the degree of information of the interviewees on the topic of climate change so that, if available, data on the level of education could indicate the level of information in a first approximation.

In addition, the level of education is also correlated with socio-economic status which is in turn an indicator for access to resources for coping with a heavy rainfall event (e. g. Wilhelmi and Morss 2012).

However, data on school leaving examinations and on the highest educational qualification are often not available at a small scale (e. g. at city district level). Collecting the relevant data is nevertheless possible and in some cases data is already available from a local authority resident survey.

Possible measures at a municipal level for the topic of appropriate behaviour:

Informing the public is important for precautionary behaviour. As early warnings are relatively unreliable in the case of heavy rainfall (e. g. Creutin et al. 2009 or Marchi et al. 2010), it is all the more important to have general information in advance. Relevant information is already been provided in some municipalities. For example, an information leaflet provided by the City of Wuppertal gives details of risks from hea-

vy rainfall, action by the city authorities, instructions for checking how much you may be affected and tips for your own protection as well as action in case of an incident. The issue of potential language barriers can be addressed here by providing information in foreign languages, for example targeted at specific parts of the city.

Topic: Resources for avoidance or repair of damage

First *structural precautions* for protecting the building such as a *backflow prevention device* are of relevance for this topic area. Second, *financial precau-*

tions are also important (*natural hazard insurance*) if damage to buildings or to household cannot be avoided.

Criterion: Structural precautions - backflow prevention device

Relevance: In order to protect buildings, besides protection to stop water entering from outside (e. g. seals, entrances located higher up), it is necessary to have protection from water entering from the sewerage system (e. g. backflow flaps). If these type of safety devices are absent, then the owner is responsible for any damage arising and in such cases there is usually no insurance cover.

There is normally no statistical data available on backflow flaps or other structural preventative measures. However, the absence of precautions of this kind is crucial for the vulnerability of the residents or the owner.

Criterion: Financial measures - natural hazard insurance

Relevance: When coping financially with damage to the building or household, it is crucially important whether this damage will be covered by an insurance. This requires having a natural hazard insurance which can be taken out as an add-on to the insurance covering house and household. Besides the financial safeguard, the terms of the insurance can also create an incentive to take precautions such as installing a backflow flap (see criterion *Structural precautions*; Birkmann et al. 2010a).

Possible measures at the municipal level for the topic of resources for avoidance or repair of damage

The promotion of structural and financial measures by private householders can be achieved by providing targeted information. Suggestions for this are provided in the information leaflets mentioned and in some municipalities there are guidelines on the protection of private property, in particular on the installation and maintenance of backflow flaps (MUNLV 2010). Examples are guidelines available on the internet produced by the Cities of Hamburg (Hamburg Wasser 2012) and Wuppertal (Wupperverband, Stadt Wuppertal and WSW Energie & Wasser AG n.a.) or from the BBK (BBK 2013) which give guidance on protecting buildings from surface water, rising damp,

ground water and seepage water and contain instructions on behavioural precautions.

According to expert interviews, heavy rainfall events often use a great deal of resources from the fire brigade, even if they result less in a direct risk to people but more e. g. in basements which have filled with water. A large number of relief units are often tied up for several hours and are therefore not available to be deployed elsewhere. It is also important from this point of view that the municipality encourages precautions by private households.

5.3 Vulnerability of critical infrastructures to heavy rainfall

5.3.1 Vulnerability of socio-economic service infrastructures

The analysis of the vulnerability of socio-economic service infrastructures proceeds from the assumption that these can represent hot spots in social vulnerability if they are exposed. Particularly *susceptible* people are those who are more likely to suffer physical injury (see remarks on the vulnerability of the population towards heavy rainfall). This is often accompanied by the lack of ability to flee from water entering the building and being unable to reach safety themselves when too few care personnel are available. A large

number of people with the limitations described are to be found in e. g. nurseries, hospitals and homes or care institutes for people with disabilities which were selected as *hot spots* for further attention. At the same time, regarded buildings can be vulnerable towards penetrating water. Partly, common rooms, surgery rooms or backup power systems are often situated in the basement, so that already relatively small amounts of water may cause larger damages.

Identifying potential *Hot Spots*

This initial list of *potential* hot spots should not be seen as exhaustive. It is only intended to provide suggestions for identifying specific institutions with a large number of particularly susceptible people

Besides the institutions mentioned here, the list could include e. g. underground car parks or factories which store chemicals. While these are not critical infrastructures as defined by the German Federal Ministry of the Interior, they could pose a risk to the population in the case of heavy rainfall. A selection of appropriate institutions can be made by using the fire brigade's fire inspection lists as a basis. The method described below can be applied in a similar way to other institutions.

Creating databases

A major problem in identifying the relevant buildings is to create a database. The categories and databases which are available in various places in the municipalities often differ markedly. Data on the buildings of relevance for civil protection are held by the fire brigade and the land registry and sometimes at other administrative offices. However, creating a common database is something to be aimed at for reasons of efficiency in carrying out and applying the results of the vulnerability analysis.

First, the exposure of these hot spots should be ascertained. Following these analyses, the *coping capacity* of the socio-economic service infrastructures will then be looked at separately.

Similarly to the exposure of the population, vulnerability of the socio-economic service infrastructures also has to be looked at on a case by case basis

for the affected buildings in order to design practical recommendations for action. However, intersecting all the relevant buildings with the depressions which have previously been calculated can limit the number of infrastructures which are actually exposed and therefore reduce the requirement for individual case studies. Figure 27 shows an example of this from a section of the City of Wuppertal.

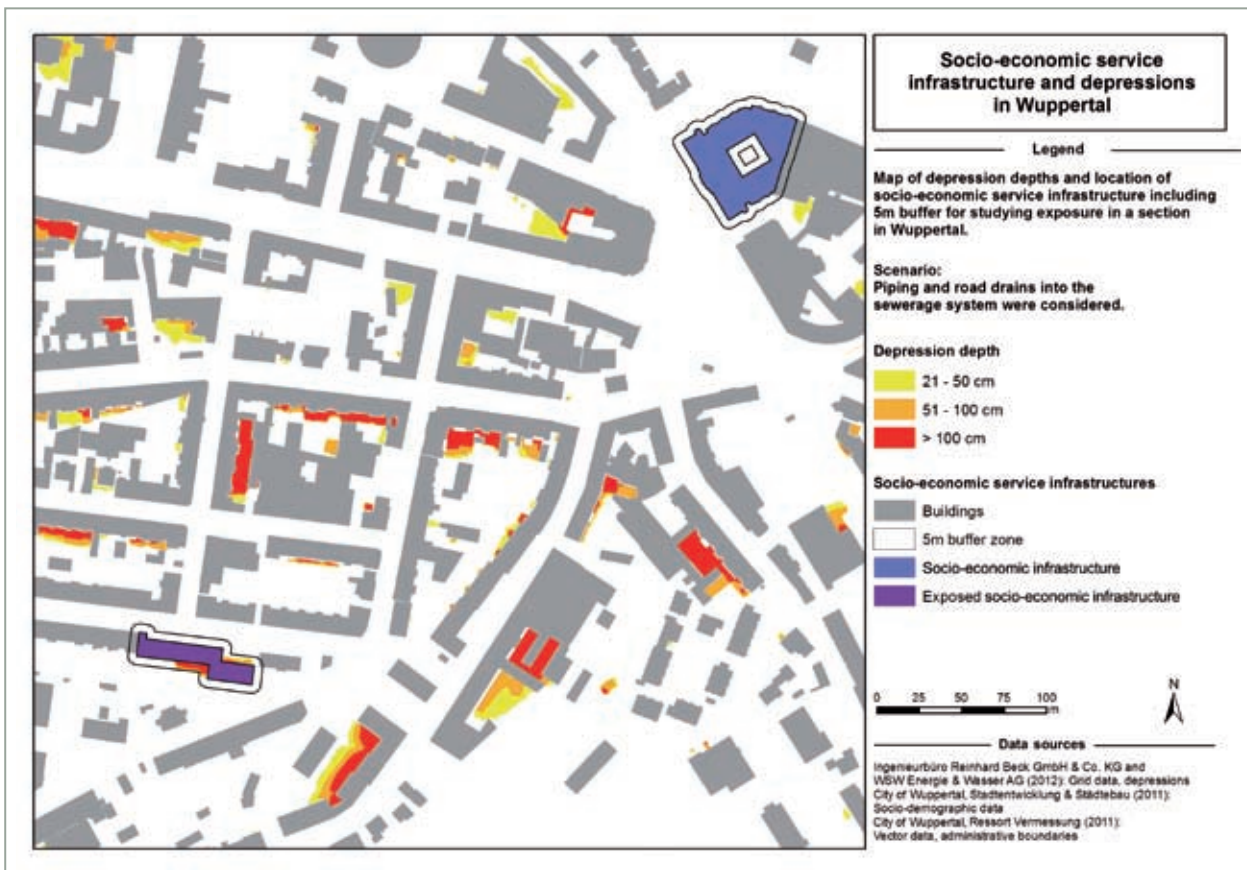


Figure 27: Exposure of socio-economic service infrastructures illustrated by a section of the City of Wuppertal

Source: own figure based on data from WSW Energie und Wasser AG, the engineering consultant Reinhard Beck GmbH & Co. KG and the City of Wuppertal.

In order to be able to determine the degree of exposure of the buildings, *buffer zones* were also set up here around the relevant buildings. If depressions with a minimum depth of > 20 cm and surface area > 1 m² are located in these buffer zones then the facility was defined as being exposed. In contrast to the residential buildings (1 m buffer zone), a buffer zone of 5 m width was selected here. This is justified

by the fact that socio-economic service infrastructures usually have larger outside areas where people can also be affected. This applies for example to access roads/entrances to hospitals or nurseries. These should initially be included in the analysis. During the subsequent individual case study it may be established that these are not affected and they can then be excluded again.

An analysis of the institutions selected for the case of Wuppertal (care homes, hospitals, day nurseries and schools) shows that only a proportion of the institutions are exposed. Table 11 illustrates this using

different radii and depression depth for determining exposure. With a radius of 5 m and a depression depth > 1 m the proportion of, for example, exposed day-care nurseries, is just at 21%.

Table 11: Exposed socio-economic service infrastructures using the example of the City of Wuppertal

Institution	Total number for Wuppertal according to the fire inspection lists	Depression depth > 20 cm (minimum surface area > 1 m ²)			Depression depth > 100 cm (minimum surface area > 1 m ²)		
		5	2	1	5	2	1
Buffer around building (in metres)		5	2	1	5	2	1
Number of exposed buildings							
Residential homes	8	6	6	6	0	0	0
Elderly homes	20	15	15	15	11	11	11
Day-care nurseries	145	86	80	78	30	27	27
Primary schools	54	34	33	32	22	21	20
Hospitals	10	9	9	8	7	7	7
Percentage of exposed buildings							
Residential homes	100 %	75 %	75 %	75 %	0 %	0 %	0 %
Elderly homes	100 %	75 %	75 %	75 %	55 %	55 %	55 %
Day-care nurseries	100 %	59 %	55 %	54 %	21 %	19 %	19 %
Primary schools	100 %	59 %	57 %	55 %	38 %	37 %	37 %
Hospitals	100 %	90 %	90 %	90 %	70 %	70 %	70 %

Source: own figure based on data from WSW Energie und Wasser AG, the engineering consultant Reinhard Beck GmbH & Co. KG and the City of Wuppertal.

The relevant (structural) measures can now be applied to exposed buildings. The study of the exposure of individual buildings can provide information, for example, which side of the building is parti-

cularly affected. At the same time the type of use of e. g. the basement rooms, should be checked and the presence of underground car parks which could perhaps be flooded.

This is particularly important when looking at the *coping capacity* of the institutions. For hospitals and also to a certain degree old people's homes, the operational reliability of the electricity and water supply are particularly important for coping with hazards. If the emergency power supply is required, then it needs to function without a problem. It should therefore be regularly maintained and tested on the one hand and, on the other, the location where it is installed is crucial. Emergency power supplies are often located in the basement which may get flooded, so that the operational capability of the emergency power system cannot be guaranteed (cf. also BBK 2008b Birkmann et al. 2010a and Section 5.3.2). Important rooms or objects are also often located on the lower floors which could be affected by the entry of water e. g. hospital entries or operating theatres.

It was stressed in the expert discussions that the availability of care staff for susceptible people had a positive effect on the coping capacity. This applies particularly if the people would otherwise have to cope on their own. In case of a natural hazard, the ratio of carers to patients will have an effect on the coping capacity. This is also affected by how much

nursing or care staff are themselves affected by a natural hazard (see e. g. Section 5.2).

So far there has been no statutory basis for calculating and identifying areas affected by heavy rainfall (see above). It is therefore up to the different municipalities how they deal with the results of the vulnerability analysis. Each fire brigade could include a discussion of this in their fire inspections as a voluntary service. This provides the opportunity to enter into dialogue with the different institutions, create an awareness of the hazard and recommend action to be taken. A solution of this type also appears to make sense because in a crisis situation the fire brigade may also reach its limits and then not be able to provide direct support. The option of including an analysis of vulnerable institutions in the fire inspections has arisen from the idea of operating in as economical and efficient way as possible. However, there is currently no statutory basis for identifying areas at risk from high rainfall so that it is not clear who should be entrusted with the relevant task within the municipality. It therefore makes sense to find out how much the fire brigade and municipal waste water authority can cooperate.

5.3.2 Vulnerability of the electricity supply

As described at the outset, the electricity supply forms the basis of modern society. Its failure can have cascading effects on a large number of other infrastructures, such as the drinking water supply, transport and the health care system. The population can therefore be affected by direct consequences (failure of power supply and therefore a range of electrical devices) and also by indirect ones (failure of other infrastructures and a potential impact on the emergency services)³⁴.

Heavy rainfall or local flooding can cause the failure of individual components. As a failure of this kind will tend to be limited due to the point occurrence of heavy rainfall events, the municipality needs to check which components could be affected in the case of an incident and how this can be handled in terms of preventative measures.

The method described first investigates the exposure of components present in the city district in order to then check their *susceptibility* and the technical and organisational *coping capacity*.

³⁴ Additional information on the effects of power failures are contained in the report by the German Federal Government (Document 17/5672) "Gefährdung und Verletzbarkeit moderner Gesellschaften – am Beispiel eines großräumigen und langandauernden Ausfalls der Stromversorgung" (<http://dipbt.bundestag.de/dip21/btd/17/056/1705672.pdf>) or by the guideline „Krisenmanagement Stromausfall“ (IM Ba-Wü und BBK 2010) (Short version: http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/PublikationenKritis/Krisenhandbuch_Stromausfall_Kurzfassung_pdf.pdf?__blob=publicationFile).

Exposure

Similarly to the selected public institutions, infrastructure components can be intersected with the calculated depressions (see Figure 28). This enables the determination of which components would be exposed in the case of an incident, as illustrated for Wuppertal. The components of the supply were first distinguished depending on their location *inside* or *outside* buildings. Geographical information on the locations

of the components were therefore intersected with the location of buildings of the city. To determine the exposure, a 2 m wide radius was then selected for all components located inside buildings. Due to their small size, a radius of 1 m was selected for the cable distribution boxes located outside buildings while a radius of 4 m was allocated to transformers³⁵.

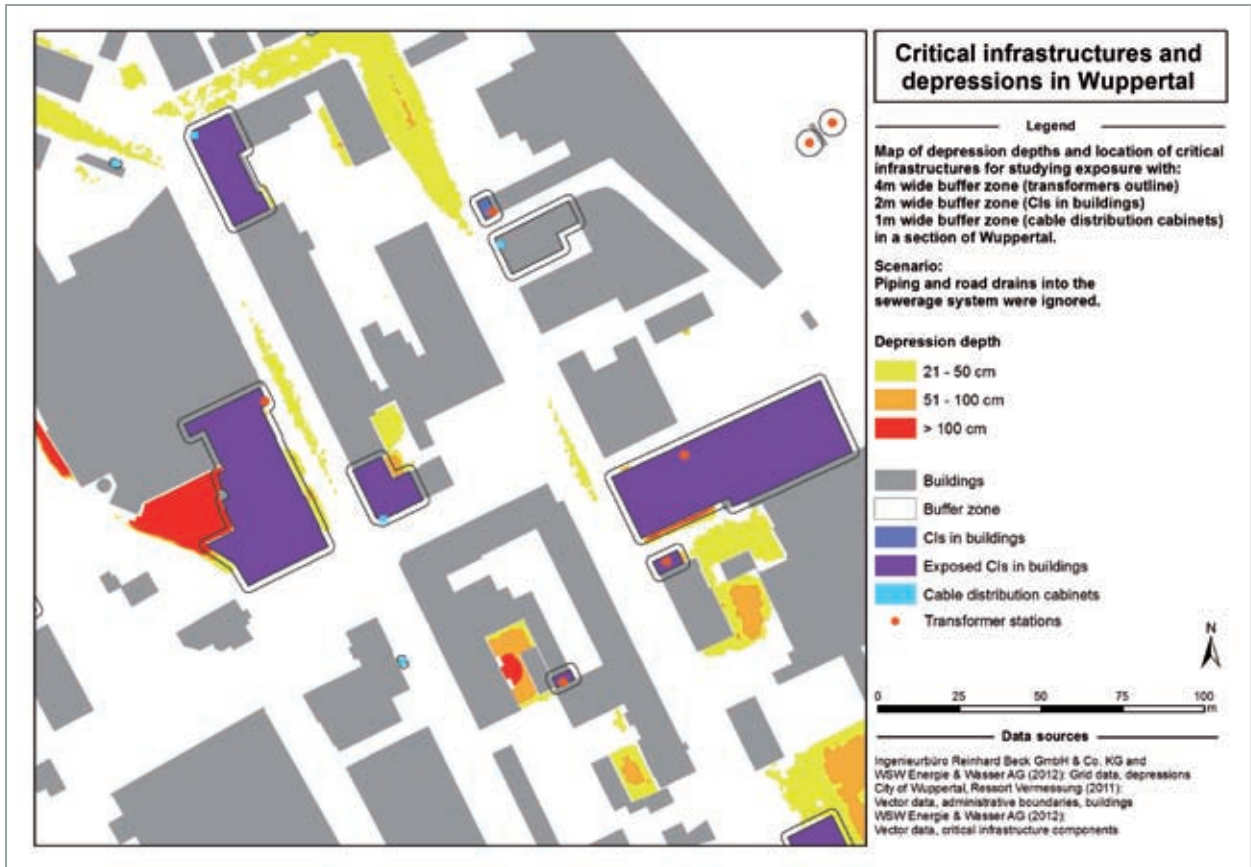


Figure 28: Exposure of critical infrastructure components illustrated by a section of the City of Wuppertal

Source: own figure based on data from WSW Energie und Wasser AG, the engineering consultant Reinhard Beck GmbH & Co. KG and the City of Wuppertal.

³⁵ The radii were determined assuming that the surrounding of buildings and components have been considered reasonably in relation to their dimensions. Information on transformer substations were only available as point data without spatial dimensions, so that a radius of 4 m was allocated for transformers.

It also appears that only a proportion of the components of the electricity supply are exposed and need to be taken into consideration for the further analyses

of susceptibility and coping capacity, as shown in the following tables.

Table 12: Exposure of components of the electricity supply inside buildings to heavy rainfall in the City of Wuppertal

CI inside buildings	Total number of components in buildings for Wuppertal	Exposed buildings in Wuppertal; Depression depth > 20 cm (minimum surface area > 1 m ²)	Exposed CIs in buildings in Wuppertal; Depression depth > 100 cm (minimum surface area > 1 m ²)
Buffer around building (in metres)	-	2	
Number of exposed CIs			
Power substation	13	8	4
Transmission substation	1	0	0
Transformer substation	1063	540	297
Cable distribution cabinets	1466	818	453
Percentage of exposed CIs			
Power substation	100 %	62 %	31 %
Transmission substation	100 %	0 %	0 %
Transformer substation	100 %	51 %	28 %
Cable distribution cabinets	100 %	56 %	31 %

Source: own figure based on data from WSW Energie und Wasser AG, the engineering consultant Reinhard Beck GmbH & Co. KG and the City of Wuppertal.

Table 13: Exposure of components of the electricity supply outside buildings to heavy rainfall in the City of Wuppertal

CIs outside buildings	Total number of components in buildings for Wuppertal	Depression depth > 20 cm; Surface area > 1 m ²		Depression depth > 100 cm; Surface area > 1 m ²	
Buffer around building (in metres)	-	4	1	4	2
Number of exposed CIs					
Power substation	1	Individual case study			
Transmission substation	1				
Transformer substation	613	100	-	47	-
Cable distribution cabinets	4200	-	193	-	91
Percentage of exposed CIs					
Power substation	100 %	-			
Transmission substation	100 %				
Transformer substation	100 %	16 %	-	7 %	-
Cable distribution cabinets	100 %	-	4 %	-	2 %

Source: own figure based on data from WSW Energie und Wasser AG, the engineering consultant Reinhard Beck GmbH & Co. KG and the City of Wuppertal.

Susceptibility and coping capacity

After all the relevant components have been intersected with the depressions in order to determine their exposure, the assessment of further aspects of vulnerability can be conducted based on an adapted form of the concept developed by Krings (2010)³⁶

(see Figure 29). Thereby it also follows the earlier described understanding of vulnerability according to exposure, susceptibility (functional susceptibility) and coping capacity (technical/organisational replaceability).

³⁶ The concept was developed as part of the previous project "INDIKATOREN zur Abschätzung der Verwundbarkeit gegenüber Hochwasserereignissen auf kommunaler Ebene" (INDICATORS for the assessment of vulnerability to flood events at municipal level).

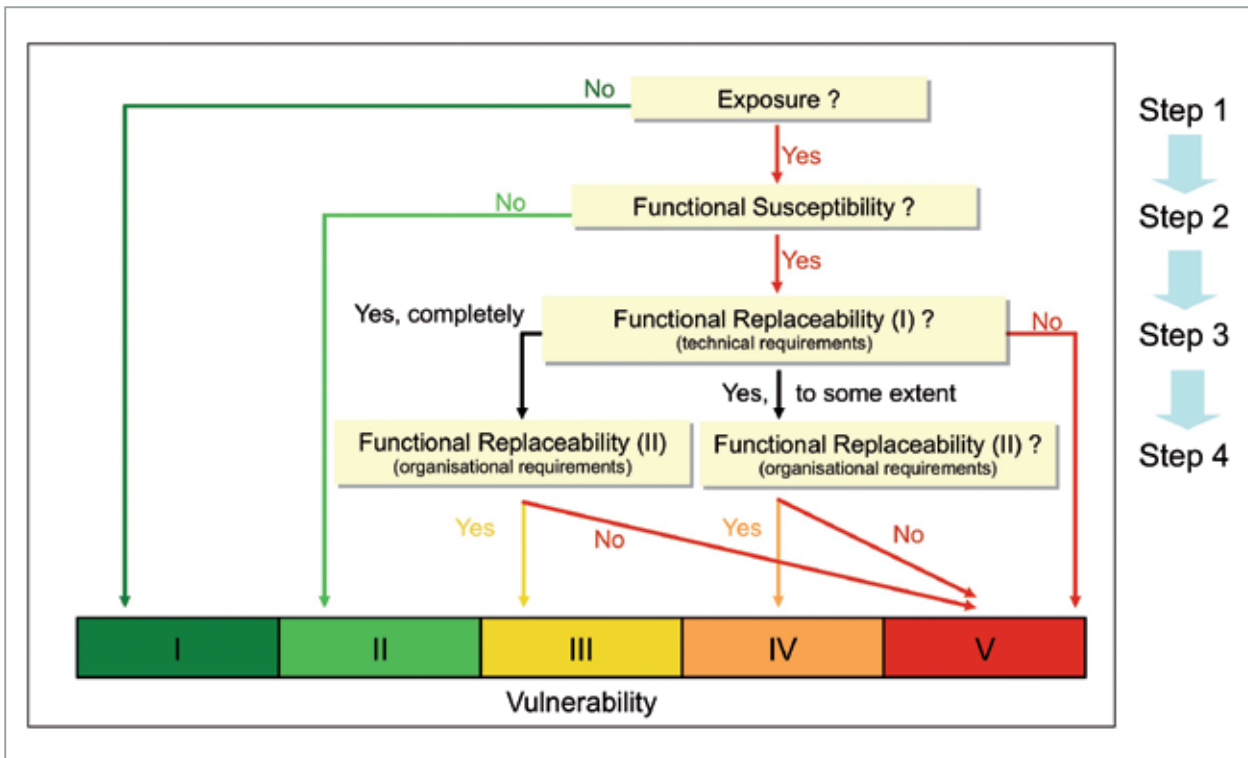


Figure 29: Concept for assessing vulnerability of critical infrastructure components

Source: own figure based on Krings 2010, p. 25.

The functional susceptibility ("would the components still function in case of being flooded?") and the technical and organisational replaceability of the components after a failure must be discussed with the appropriate experts on the ground. Every com-

ponent may have a different technical design or age from other components and therefore demonstrate varying characteristics in terms of susceptibility and coping capacity.

Cooperation between local authorities and operators

An analysis of the vulnerability of the electricity supply is easiest if the local authority itself is involved in running the supply, for example via municipal utilities. However, if this is not the case, then it

needs to be decided to what extent an analysis of the exposed supply in terms of susceptibility and coping capacity can be undertaken cooperatively. Information should then be exchanged at defined interfaces. It is useful in this respect to set up round table discussions to improve civil protection.

It must always be borne in mind that the effects of component failure differ depending on their hierarchy. For example, if a substation fails, this affects more people than the failure of a cable distributor. What is more, *higher ranking* components usually have a lower coping capacity as they cannot be immediately replaced if they are destroyed.

At the same time, there is in general redundancy at the higher levels of the electricity supply (e. g. power plants, substations, transformers) which, by appropriate switching, can supply the affected areas at least in part if the local grid topography permits. For this reason, knowledge of the vulnerability of the individual components is of crucial importance as it can serve as a basis for alternative emergency connections.

Despite these technical options, the potential failure of components due to a heavy rainfall event is fraught with further problems. On the one hand this is due to the time when the *switch-over* to an alternative distribution takes place. Suppliers can activate an emergency connection, for example based on early warnings or if heavy rainfall sets in. It is also possible to e. g. switch off areas which might become flooded and in which there is then a risk of electric shocks. As however, according to the suppliers,

this can involve a possibly unnecessary power cut for households and/or businesses and can involve corresponding compensation payments, an attempt is often made to avoid this.

Besides the risk of electric shocks, there is also the possibility that the power supply – e. g. triggered by an incorrectly implemented switching process – can fail in some areas. Possible effects and corresponding preparatory options for such an event are therefore dealt with as part of the *2nd assessment* step (see Chapter 6). This is important in order to carry out a comprehensive analysis of the vulnerability of the municipality, also taking vulnerability to power failures into account.

It should be borne in mind that a power failure which is due to a natural hazard almost inevitably leads to particular problems which would not occur in a *simple* failure. The occurrence of heavy rainfall as the trigger for/at the same time as power cuts is a particular problem in relation to pumping out water as the use of pumps requires a functioning electricity supply. Situations like these which reinforce each other should therefore be borne in mind as part of the preparation.

VI. Chapter

Vulnerability assessment of the municipality to power failures:
implementation of the 2nd assessment step using
qualitative criteria

The events in Münsterland in 2005 and the effects of windstorm Kyrill in 2007 have demonstrated strikingly what consequences natural hazards can have for the electricity supply. Set in motion by a large amount of wet and therefore heavy snow accompanied by strong winds, a large number of masts and wires collapsed in Münsterland. Around 250,000 people were without power for up to five days (Bundesnetzagentur 2006; THW 2005). Kyrill also caused power cuts in some parts of Germany from falling trees which were difficult to clear due to the blocked roads (cf. e. g. Ebertz 2012).

This hereafter presented questionnaire should help local authorities to analyse the potential effects of power failures which have been triggered by extreme weather events, where the power failure is assumed to have a considerable spatial extent over a long period. This chapter is therefore intentionally not connected to the two hazards of heat and heavy rainfall. While these are potential triggers of power failures, other causes such as human or technical failure may be involved. In terms of a comprehensive assessment of the vulnerability to natural hazards, it is important to include the vulnerability to power failures as a second step. At the same time it is useful to have an assessment of this kind separate from the natural hazard if municipalities want to address how to deal with power failures in general. The checklist serves as a first approximation of the topic of power failure.

If an area is affected by interruptions to the supply or even damage to the infrastructure due to the effects of natural hazards, the suppliers will attempt to reinstate the power supply as fast as possible (and carry out any necessary repairs). It is essential for them to know the cause of the failure. The protective measures, on the other hand, will focus on the control and containment of the effects of the power failure and for this it is important to know the effects on and potential vulnerabilities of the population.

In order to link the different spheres of activity of the various players as effectively as possible, in the case of such an incident it is helpful to develop a joint

communication strategy between the operators and the local authority. This will establish which information (e. g. assessment of the duration of the power failure, appeal to the public to save electricity in the case of shortages etc.) should be exchanged and what information should be made available when and how to the public.

Overall the list of questions also follows the concept of vulnerability (cf. e. g. Birkmann 2013 and Chapter 3). For *exposure* the *power failure* scenario is assumed to apply to the whole municipality. *Susceptibility* is described using particular *dependencies* on the electricity supply while the *coping capacity* is defined by the level of preparation of the emergency services/population/CI operators and companies.

The questions posed in what follows can serve as a basis for testing the vulnerability of the municipality to power failures. These questions are intended as central issues which should be a guide to identifying areas of activity and potential measures so that the list is not to be seen as exhaustive and does not replace the study of regulations, guidelines and other checklists for a comprehensive analysis of the topic – relevant further reading is mentioned in the course of the chapter. The checklist comprises general aspects which in some municipalities may already be recognized and prepared accordingly, while other municipalities – perhaps because there have been no large-scale power failures in the past – have barely looked into the subject so far. It should help to sensitise the municipalities for the potential effects of blackouts. The potential affectedness of different actors such as civil protection agencies, population as well as operators and businesses are addressed in order to depict their mutual dependence. The checklist thus also aims at raising awareness for these interdependencies and to improve the cooperation of the actors since preventative civil protection with respect to blackouts can only be successful in a comprehensive way.

Other infrastructures such as the drinking water supply or information and communication systems are dependent to varying degrees on the electricity

supply. It is therefore useful to record precise dependencies specifically for the municipality with the operators of the electricity supply and the various operators of the CIs at a round table discussion. The report by the German Federal Government (Document 17/5672) "Gefährdung und Verletzbarkeit moderner Gesellschaften – am Beispiel eines großräumigen und langandauernden Ausfalls der Strom-

versorgung"³⁷ and the handbook "Krisenhandbuch Stromausfall" (IM Ba-Wü and BBK 2010)³⁸ can be consulted for a preparatory analysis of the municipality in relation to the potential effects of power failures. These present potential effects on other areas of the infrastructure and indications for the course taken by such effects over time.

Excursus: Regulatory areas for the electricity supply

In principle there are different regulatory areas which relate to (partial) power failures. If faults or threats to the safety or reliability of the energy supply occur, it is initially part of the transmission system operator's (TSO) responsibility to take the necessary action. In accordance with para. 13 I German Energy Industry Act (Energiewirtschaftsgesetz – EnWG) this initially consists of

- grid related measures, particularly grid connections and
- market related measures, particularly the use of the operating reserves, contractually agreed

interruptible and connectable loads, information on shortages and management of shortages plus mobilization of additional reserves.

If a threat or fault cannot be eliminated or not eliminated in time by such measures, then, as part of the cooperation in compliance with para. 12 I EnWG, the operators of transmission systems are justified in and obliged to adjust all electricity feed in, transmission and supply in their regulatory zones to the requirements of a safe and reliable operation of the transmission grid or to demand this adjustment (para. 13 II EnWG), as shown in Figure 30.

³⁷ Available at: <http://dipbt.bundestag.de/dip21/btd/17/056/1705672.pdf>

³⁸ The short version is available at http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Publikationen/Kritis/Krisenhandbuch_Stromausfall_Kurzfassung_pdf.pdf?__blob=publicationFile.

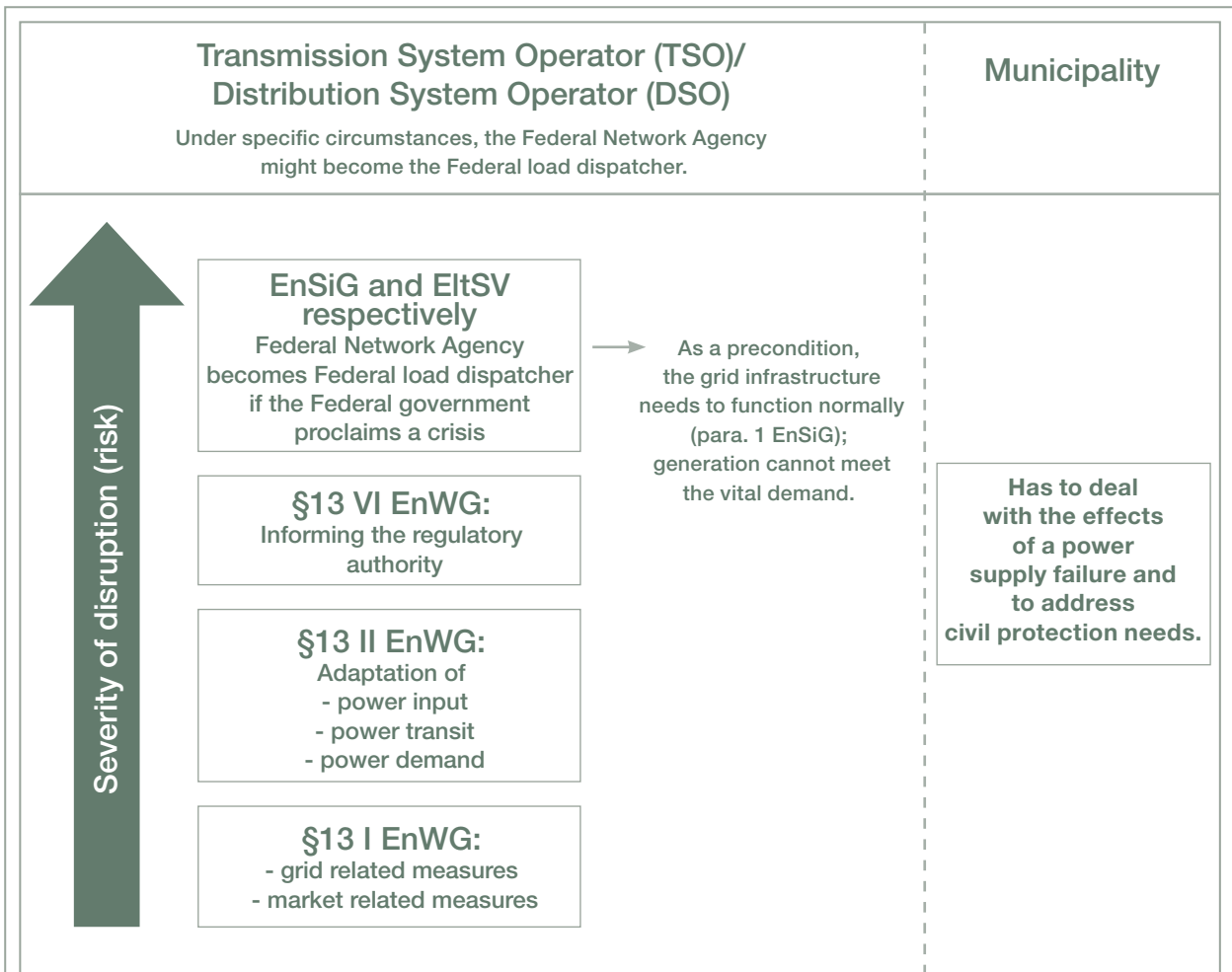


Figure 30: Measures in case of a threat to/fault in the electricity supply

Source: own figure.

Potential load shedding is carried out by the TSO in 5-stage plan³⁹ shown in Table 14. order to guarantee the mains frequency under the

Table 14: 5-stage plan to control major faults with frequency drop

Step 1:	49,8 HZ	Alert personnel and deploy the generation capacity not yet mobilised on the instructions of the TSO
Step 2:	49,0 HZ	Shed 10-15% of the system load immediately.
	48,7 HZ	Shed a further 10-15% of the system load immediately.
Step 4:	48,4 HZ	Shed a further 15-20% of the system load immediately.
Step 5:	47,5 HZ	Disconnect all generating plants from the grid.

Source: VDN 2007, p. 9.

³⁹ "Netz- und Systemregeln der deutschen Übertragungsnetzbetreiber" (TransmissionCode)

The corresponding load shedding is prepared in advance by means of the necessary switching. In this situation operators aim in particular for what it is technically possible to implement and what will be effective, as it may be necessary to shed 50% of the load within a very short space of time. There are various options for dealing with the necessary load shedding such as agreed policies for shedding large loads⁴⁰.

If these measures are still not adequate for averting a disruption to the supply for essential needs in terms of para. 1 of the Energy Security Act (EnSiG), the transmission systems operator (TSO) must inform the regulatory authority (Federal Network Agency) immediately. In the case of particular severity of the fault, as an additional step the Federal Government can put the Energy Security Act (or the accompanying Electricity Security Regulation) into force. Under specific conditions, the Federal Network Agency would become the load distributor. However, load distribution assumes that the grid infrastructure is able to function normally (see also Figure 30). If this were to result in a reduced energy supply (system balance disturbances through lack of supply), then the distribution grids (and the municipalities which depend on them) would be switched off and on again at defined intervals (cf. e. g. VKU and BDEW 2012). This situation is not described in any greater detail here. If it was no longer possible to supply electricity from the transmission grid for example due to very serious damage to the infrastructure at transmission system level, municipalities could try to establish a power supply using their own distribution/urban grid as far as possible.

If, due to faults in the transmission grid, a reduced generation of electricity or other causes, the loads

in the distribution/urban grid needed to be reduced or there was even a blackout, this would have a direct impact on the population. In order to minimize these effects as much as possible, the local authorities should approach the local operators in advance to discuss and agree potential measures. This increases mutual understanding (What do the emergency services do? What happens on the operator's side in the case of a power failure?) and sound measures can be jointly established. These include, for example, a request to the public to save electricity in the case of supply shortages. In addition, communication routes can be set up and reinforced for the disaster. Some German distribution system operators automatically notify the relevant authorities about planned and unplanned disconnections.

If disconnections have to be made at the level of the local distribution network operators, then the local authority can define important facilities in consultation with the network operator which (if technically possible) can be supplied as a priority using appropriate switching. While, in accordance with EnWG, it is the responsibility of the network operator to ensure a safe, stable and non discriminatory grid operation, at the same time in accordance with the law of the specific Federal Land, the local authorities are responsible (by maintaining fire brigades) to provide assistance for accidents and such states of public emergency as are caused by natural events, explosions or similar incidents. The higher (regional) districts direct and coordinate operations if the life and health of a large number of people are at risk and back-up support is required by the incident command which cannot be provided by the municipality (major catastrophic event) (cf. e. g. para. 1 FSHG⁴¹).

⁴⁰ Based on para. 13 IVa EnWG in conjunction with the *Verordnung zu abschaltbaren Lasten (AbLaV)* (ordinance on interruptible loads).

⁴¹ Law on fire prevention and assistance of North Rhine-Westphalia.

The local authorities and distribution network operators should cooperate as well as possible in the interests of civil protection within this area of differing responsibilities.

"To prevent and overcome serious faults and severe damaging events it therefore needs institutionalised and organised cooperation between the government and private enterprises by the means of established security partnerships."

(BMI 2009, p.8)

Overview of spheres of activity for dealing with power failures

The list of questions to record the vulnerability of municipalities to power failures is based on 15 iteratively conducted expert interviews and basically divided into four areas. The first area can be defined as *communication or cooperation between local authorities and operators* and generally deals with the structure of energy supply in the municipality and with the cooperation between the local authority and the operator(s). The three further areas comprise the *players* who have a role in relation to power failures, namely the public and important institutions such as

hospitals or elderly homes, emergency services and operators of CIs and businesses based in the municipality.

Vulnerability to power failures is determined for all three players by examining the dependency on the supply (susceptibility) and the preparatory measures in place (coping capacity). The differing areas for analysis can be summarised as follows (see Table 15):

Table 15: Overview of spheres of activity for dealing with power failures

Communication and cooperation between local authorities and operators
Contact to supply network operators
Structure of the municipal energy supply
Joint planning by emergency services and distribution network operators (operations planning, communication, definition of vulnerable institutions, exercises)
Vulnerability of the population to power failures
Dependency
Identification of particularly electricity dependent persons and institutions
Level of preparation
Potential power supply for especially dependent people and institutions (emergency power, priority supply)
Communication with the public
Emergency shelters for the public
Supplying the public
Vulnerability of emergency services to power failures
Dependency
Dependency of emergency services on the power supply
Alerting staff during power failures
Level of preparation
Availability of emergency power within the emergency services
Communication during a power failure (e. g. satellite communication, radio links)
Operation plans and definition of tasks
Employee provisioning
Fuel requirements and alternative fuel supply
Vulnerability of operators of critical infrastructures and businesses to power failures
Dependency
Taking account of power failure scenarios for operators of CIs and businesses and assessment of economic consequences
Taking account of cascading effects
Level of preparation
Availability of an energy power supply
Personnel and organisational preparation

Source: own figure based on expert interviews.

For the four areas

1. Communication and cooperation between local authorities and operators,
2. Vulnerability of the population to power failures,
3. Vulnerability of emergency services to power failures and
4. Vulnerability of operators of critical infrastructures and businesses to power failures,

questions are listed in the following four sub-sections to guide the local authority in assessing their vulnerability to power failures and presenting potential areas of action for reducing these. The assessment of vulnerability of the municipality to power failures should include all areas of analysis with the questions being answered in sequence. However, it must be borne in mind that, even if the answer to most

questions is *Yes*, it is never possible to be absolutely certain as every power failure is accompanied by unknowns.

While working through the checklist, the information obtained should be documented and made available for other parties. This can be done for example using a reference file such as a folder where unresolved issues and existing information as well as helpful tips can be stored. To assist in this process, the checklists have room for notes. Records can be kept here of e. g. relevant contacts or responsibilities and filing locations etc. which are later transferred to the reference file. When working through the checklist it is possible that questions cannot be answered conclusively by the local authority because e. g. measures have not been fully implemented or the relevant information is not available to the person dealing with the matter. This should then be taken as an incentive to acquire additional information or initiate further measures.

6.1 Communication and cooperation between local authorities and operators

Contact to supply network operators

1. *Is there contact with the the supply network operator(s)?*
 - Yes. → Who is the local authority contact for disaster management? (The relevant contact data should be available in an emergency file)
 - No. → As part of disaster management you should make contact with the supply network operator. (existing contacts from other departments of the public administration e. g. the urban / regional planning dept. can be used if necessary)
2. *Is there a communication strategy between the emergency services and the supplier to safeguard communication in case of a power failure? Has the need for mutual information exchange been expressed and have technical fallback levels in communication been defined?*
 - Yes.
 - No. → As communications can also break down after a relatively short time during a power failure, the remaining time should be used as effectively as possible. A suitable communication strategy can be helpful for this.

Structure of the municipal energy supply

3. *Do you know what the structure of the energy supply in your municipality is? Do you know the spatial distribution of the local suppliers and the number of feed-in points from the transmission grid for the local electricity supply?*
 - Yes. → It is nevertheless important to take into account that these structures are subject to constant change so that information should be checked at regular intervals. In addition, information on the structure of the grid is not enough for effective disaster management (see further questions).
 - No. → You should find out about the relevant structures from the distribution network operator responsible as these have a fundamental effect on potential risks and appropriate action. Besides the number of feed-in points from the transmission grid, this includes the number and type of power plants if any. These determine the potential alternative supply strategies for example if a feed-in point fails and the possibility of having a stand-alone operation.

Notes

(e. g. regarding contact persons, contact details or required actions)

4. Do you know whether there are local power generating plants (e. g. a combined heat and power plant) in your municipality?
- Yes. → How many are there and where are they located?
 - No. → You should ascertain from the operator(s) responsible for your municipality whether such plants exist.
5. Can these components of the power grid supply your municipality in stand-alone operation?
- Yes. → It is nevertheless important to take into account that these structures are subject to constant change so that information should be checked at regular intervals.
 - No. → The support of decentralised plants can reduce the vulnerability of the municipality to power failures. This includes those kind of power plants (e. g. combined heat and power plants) with black-start capability, in other words which can be started independently of the power grid and therefore enable stand-alone operation. When dismantling redundancies of this kind (e. g. for cost reasons) the effects on the vulnerability of the municipality should be kept in mind.
6. Load shedding is the name given to disconnection of a consumer from the electricity grid which then causes a power cut for the respective consumer. Load shedding is a means of stabilising the grid and is carried out in accordance with a non discriminatory procedure. Do you know the load shedding aims of the operator in the case of planned or unplanned consumer disconnection? Do you know which institutions/businesses/city districts would be disconnected first in order to ensure an efficient decrease in load?
- Yes, the load shedding is known and the relevant facilities have been identified. → You should ensure that this information is also included in the precautionary planning and that the relevant institutions/businesses are aware of their situation.
 - No. → You should learn the planned or possible load shedding or (better) discuss it in terms of the technical possibilities with the supplier.
7. Which institutions are identified as particularly vulnerable to power failures and require special awareness in case of a power cut? (The facilities mentioned are examples: the list is not exhaustive.)
- Emergency services
 - Hospitals
 - Nurseries
 - Elderly homes
 - Other basic technical infrastructures (e. g. water supply, sewage disposal, transport incl. local public transport, information and telecommunication systems, etc.)
 - Doctors' surgeries
 - Dialysis clinics
 - Public authorities
 - The courts

Notes

(e. g. regarding contact persons, contact details or required actions)

- Banks
- Prisons
- Museums (potential loss of objects of cultural value due to power failure)
- Zoos (temperature control of enclosures may not be possible due to power failure)
- Emergency facilities/"warm rooms" in which people can be looked after during a power failure.
- Other

It must be borne in mind that although some institutions and organisations such as hospitals have emergency power supplies, these may not function or, during power cuts lasting for long periods, may not be able to be supplied with fuel as pumps and filling stations cease to work. In addition, the emergency power supply is not a full replacement for the ordinary power supply. Often only the most important parts of the hospital are supplied. Furthermore, it should be checked whether the emergency power supply has been adapted to the structural and technical developments in the hospital.

For clarification: although emergency power supplies in hospitals are regularly tested, a full changeover to the emergency power supply is often not carried out for safety reasons. The institution remains connected to the local supply grid in parallel. It is therefore not certain in such cases whether a full switch-over to an emergency supply system will actually function in an event. As far as possible, emergency services should run tests to practice switching over completely to the emergency power supply.

Independently of this, checks should be made as to whether external service providers on which the hospital relies e. g. for catering supplies, laundry or sterile equipment would function during a power failure. At the same time, problems with the water supply which could be caused by the power failure will have a particular effect in terms of hygiene.

8. *Do these include facilities which would be affected by load shedding*

- Yes. → A check is required as to whether these facilities can be prioritised in terms of electricity supply in the case of a shortage and which criteria can be used to define this supply.
- No. → It must be assumed that – although technically possible – the facilities may not be prioritised in terms of electricity supply.

It should be borne in mind that the operation of the grid remains the responsibility of the network operator, but voluntary cooperation to improve civil protection can be aimed for.

Notes

(e. g. regarding contact persons, contact details or required actions)

9. *Is the network operator aware of particularly susceptible institutions (e. g. hospitals)?*

- Yes. → Has the possibility of a priority supply been jointly discussed?
- No. → A joint overview of the relevant facilities should be compiled and the possibility of prioritising discussed.

10. *Within the municipality, have you discussed issues relating to development of the grid and the corresponding effects on the security of the energy supply and the technical feasibility of maintaining the supply for specific facilities (prioritisation) as part of civil protection?*

- Yes.
- No. → You should discuss the operator's plans for further development of the grid (grid topology) and the technical switching options which may arise from this.

Joint planning by emergency services and distribution network operators

11. *Is there a joint operation plan between the emergency services and the distribution network operators which sets out the responsibilities and cooperation for dealing with power failures?*

- Yes.
- No. → You should examine whether it is possible to have a joint operation plan and put this into practice. Appropriate operation plans can be based on existing ones such as were developed in cooperation with the chemicals industry, for example. It is helpful to define different levels of escalation in order to adapt the operation plans as specifically as possible to the situation.

12. *Which suppliers belong to the municipality's emergency team which will be deployed during a power failure? Which suppliers might be included in the relevant exercises (see also e. g. "Hinweise zur Bildung von Stäben der administrativ – organisatorischen Komponente" [Verwaltungsstäbe - VwS] and the DV 100)? (The relevant contact details should be put in your emergency file.)*

- Electricity
- Gas
- Water
- Waste water
- District heating
- Telecommunications
- Other

13. *Is the demarcation between the emergency team and the emergency services' operation management clearly defined?*

- Yes.
- No. → You should delimit the responsibilities between the emergency team and the operational management for the power failure scenario.

Notes

(e. g. regarding contact persons, contact details or required actions)

14. Have exercises/table-top exercises for the power failure scenario been carried out?

- Yes.
- No. → You should carry out an exercise of this type and include all the relevant players especially the supply network operator and other infrastructure operators (cf. e. g. Leitfaden für strategische Krisenmanagement-Übungen (guideline for strategic crisis management exercises) of the BBK).

Note that different work shifts may be affected by the failure and that staff may change continuously. The exercise may need to be carried out more than once in order to familiarise the greatest possible number of staff with the subject.

Also bear in mind that, besides cooperation in the emergency team and using exercises to improve how such emergency situations are dealt with, the definition of levels of escalation can also be useful. At which point (e. g. failure in minutes) or which level of failure (e. g. 30% of the service) should the emergency team take action?

In addition, consideration of site-specific threshold values for the failure of additional infrastructures such as the drinking water supply could lead to advance identification of other problem situations over time.

Notes

(e. g. regarding contact persons, contact details or required actions)

Remedial measures

15. Have you planned the remedial measures after a power failure?

- Yes. → For which areas have plans been made?
- No. → You should also plan the transition to normal conditions. For example, members of staff have to be informed. Repairs may be necessary and infrastructure systems may have to be recommissioned. There may be large quantities of waste (e. g. food which has gone off due to the failure of fridges and freezers) to dispose of (see also e. g. Sections N-A-1 to N-A-3 of the *Krisenhandbuch Stromausfall*).

6.2 Vulnerability of the population to power failures

Besides preparations by the emergency services lined out in chapter 6.3, the potential consequences of a power failure for the population should be assessed as well as possible effects so that the necessary preparatory measures can be taken. It is important to identify particularly susceptible people in advance in

order to be able to develop precautionary measures *jointly* with them if needed. People in need of assistance cannot necessarily depend immediate help during a power failure as the emergency services may also be overstretched.

"Currently there is no uniform risk and disaster management strategy for companies, the government and other players. The level of awareness is limited and the ability for self help amongst the public very low."

(Reichenbach et al. 2008, p. 27)

6.2.1 Dependency

Identification of particularly dependent persons and institutions

1. *Do you have an overview in your municipality of the people who are particularly dependent on the electricity supply? This applies particularly to residents who are dependent on the operation of electrical medical devices such as patients on dialysis or ventilators and those who are being operated in outpatient clinics and could wake up from the anesthetic if the power fails. In addition, there are people who are particularly dependent on an uninterrupted supply of drinking water and food, such as infants/small children, etc.*

- Yes.
- No. → It is of fundamental importance to be aware of particularly vulnerable people in order to set priorities in the operational planning. In view of the large number of people involved, these might not all be able to be supplied in the case of a power failure. As part of the preparatory planning the specified groups of people could nevertheless be informed of particular problem situations in order to make preparations themselves. However, the availability of data on particularly susceptible groups of people is very varied. For example, while there might be records of the houses of critically ill patients there are generally no data on people being nursed at home. The data available for outpatient clinics varies from one municipality to the next. Social security offices may

Notes

(e. g. regarding contact persons, contact details or required actions)

have data on those in need of nursing care, for example. Private households should be made aware that electrically operated medical devices should run on an uninterruptible power supply.

Notes

(e. g. regarding contact persons, contact details or required actions)

6.2.2 Level of preparation

Besides particular susceptibility to power failures, the degree of preparation can be an important source of information for the development of response measures. For this reason, targeted information campaigns on the topic of power failures can raise public awareness and can encourage precautionary measures such as laying in supplies.⁴²

A particular challenge for improving the level of preparedness is presented by the low level of public awareness of the problem and the resulting lack of measures for dealing with it (e. g. Lorenz 2010 or Reichenbach et al. 2008) such as having a stock of drinking water and food. Due to the potential failure of electronic payment devices as well as of cash dispensers and computer systems in banks, there may be only a limited supply of cash. In addition, the failure of cooling systems and transportation must be

anticipated, so that food and drink may not be available for purchase in case of a disaster. Further, it must be assumed that point of sale systems and electric doors and lifts will no longer work so that shops will have to close (see also Reichenbach et al. 2008).

The ability of people to help themselves is developed to very varying degrees in different places. It is basically assumed that the coping capacity in the country is higher than in the town which is partly due to less dependence on just-in-time processes and less serious hygiene problems which could arise from the failure of waste disposal services (Lorenz 2010). At the same time it must be realised that many agricultural enterprises can only be operated with the help of electricity (e. g. electrically operated milking parlours) and if livestock farming is included, then the need for help increases by several factors.

Possible electricity supply for particularly dependent persons and facilities

1. *Can the particularly dependent (groups of) people and facilities be supplied with emergency generators?*

- Yes. → It should be checked in advance as to who will carry the costs incurred.
- No. → The implementation of alternative action strategies (e. g. prioritisation by the supplier, own preventative measures) should be checked (cf. also the following question). This option should be viewed in connection with Question 1. on the dependency of the population.
- Partly. → As presumably there are only a few emergency generators available, agreement must be reached as to which facilities should reasonably be supplied with these.

⁴² See also the sub-heading *Further reading* at the end of this section.

2. Are there alternative action strategies for supplying people and facilities with emergency generators?

- Yes. → What form do these take?
- No. → You should check how the relevant facilities and people will be dealt with in the case of a power failure if there are no emergency power supplies available or these do not function and they cannot be supplied with emergency generators by the emergency services.

It should be determined whether institutions/people can be evacuated and accommodated in shelters which are supplied with emergency power. However, it may not be guaranteed that all dependent persons can be looked after during a large-scale power failure. Institutions and private individuals can be made aware of this and encouraged to look after themselves or be notified of possible shelters which they might be able to find on their own.

3. Have you informed the relevant emergency services about the people and institutions affected? Are they aware of the strategies for power failures?

- Yes.
- No. → It should be ensured that the emergency services in your municipality have discussed the relevant strategies with each other and know their particular responsibilities.

Communication with the public

4. Is there any contact with the local radio stations which could pass on important information to the public in case of an incident?

- Yes. → Remember that this may only reach those with battery operated radios.
- No. → You should get in touch with the local radio stations and ensure that important information can be passed on in case of an incident. However, remember that this may only reach those with battery operated radios.

5. Are megaphones and suitable batteries available?

- Yes. → Where are these kept and who is responsible for them?
- No. → Suitable devices and the batteries required for their operation should be provided as an alternative means of communication with the public.

6. Is there any possibility of producing leaflets and informing the public by this means?

- Yes. → How will this be done and who will be responsible? "Gap texts/cloze exercises" might be prepared for a respective situation.
- No. → You should check alternative means of communication which can be used in the event of a power failure.

Notes

(e. g. regarding contact persons, contact details or required actions)

Emergency shelters for the public

7. Are there plans to set up shelters for the public?

- Yes.
- No. → You should consider which institutions (for example schools, town or gym halls) can be used as shelters for the public.

For setting up supply stations, for example, it could be useful to use the concept of "Betreuungsplatz-Bereitschaft 500 NRW" (BTP-B 500 NRW).⁴³ This can look after and feed 500 people on the assumption that a suitable building (e. g. school, multipurpose hall or similar) is made available by prior arrangement. The size of such "warm rooms" must naturally be adapted to local requirements.

When considering shelters or what are known as "warm rooms", fire stations are often taken into considerations but these are not really suitable as the operation deployment is being carried out there.

8. Are these shelters known to both the public and the emergency services?

- Yes.
- No. → You should ensure that the emergency services are all aware of the shelters. The public should also know about the relevant shelters as this reduces the communication effort in the event of an emergency.

9. Are the shelters illuminated or marked in some other way?

- Yes.
- No. → You should consider how the public can be informed in advance or made aware of the shelters during a power failure.

10. Have the shelters been agreed with the network operator? (see also Section 6.1 on communication and cooperation between the municipality and the operator.)

- Yes. → A check should be made as to whether the shelters can be supplied as a priority – if this is technically possible.
- No. → It must be assumed that the shelters are not supplied with electricity.

11. Do the shelters have an emergency power supply?

- Yes. → The power rating of the generators and therefore their estimated operating time should be noted in the reference file. Refuelling should also be ensured by means of appropriate contracts and arrangements. The information on this (contact details, flow chart) should be noted in the reference file.
- No. → It should be checked whether these can be supplied by mobile emergency generators in case of emergency.

Notes

(e. g. regarding contact persons, contact details or required actions)

⁴³ http://www.idf.nrw.de/service/downloads/pdf/20090731_konzept_btp_b_500.pdf.

12. What needs can the shelters meet (possibly without any emergency power)?

(The following points should be checked for each shelter individually.)

- Power
 - Dialysis
 - Artificial ventilation
- Heating
- Cooking facilities/hot food
- Provision of drinking water and food
- Beds
- Provision of medicines
- Other

13. Can the shelters also be used as reception points for emergency calls?

- Yes.
- No. → Consideration must be given to how the public can make emergency calls during a power failure and while the information and communication systems are down.

Supplying the public

14. Has the public been informed about the possible occurrence of a power failure and the resulting effects?

- Yes.
- No. → As part of the disaster risk management, the public should be informed about the possibility of a power failure and the potential consequences of this.

15. Has the public been made aware of potential precautionary measures?

- Yes.
- No. → The public should be informed of this using existing materials in order to take appropriate precautionary measures such as laying in supplies. Please refer to e. g. "Für den Notfall vorgesorgt" by the BBK (2012c) or the "Krisenhandbuch Stromausfall" (IM Ba-Wü and BBK 2010).

16. Are there medicines and food and drinking water supplies available in the municipality which can be used to supply the public?

- Yes.
- No. → A check should be made as to the feasibility of maintaining such supplies. It should also perhaps be considered how the population can be encouraged to keep their own supplies.

17. Has any thought been given to involving local supermarkets in the supply in emergency situations?

- Yes. → The relevant agreements should be noted in the reference file.
- No. → Arranging supplies through the supermarkets who may be in receipt of emergency power from the emergency services can be planned and organised throughout the area of the municipality in case of need.

Notes

(e. g. regarding contact persons, contact details or required actions)

18. *Can the drinking water supply be guaranteed by the local water company?*

- Yes.
- No. → You should establish whether this alternative strategy can be developed for cases of emergency. Otherwise it must be assumed that the public may not be able to be supplied with adequate amounts of drinking water.

19. *Do you know the locations of the emergency wells which may be able to ensure a supply of drinking water?*

- Yes.
- No. → You should locate the sites of emergency wells in your municipality and keep a note of these in paper form.

20. *Are the logistics for transporting and treating the water guaranteed?*

- Yes. → Who is responsible for this and where can the necessary containers be obtained?
- No. → You should ensure that this can be implemented in case of an incident, both technically and organisationally (staff training, availability of transport containers, etc.).

Notes

(e. g. regarding contact persons, contact details or required actions)

6.3 Vulnerability of emergency services to power failures

Due to the power failure and potential cascading effects on other infrastructures, the question arises as to what extent the emergency services themselves would be affected and therefore restricted in their

ability to act while simultaneously being under greater pressure. The potential for assistance would be influenced by the extent of the power failure, as shown in Figure 31.

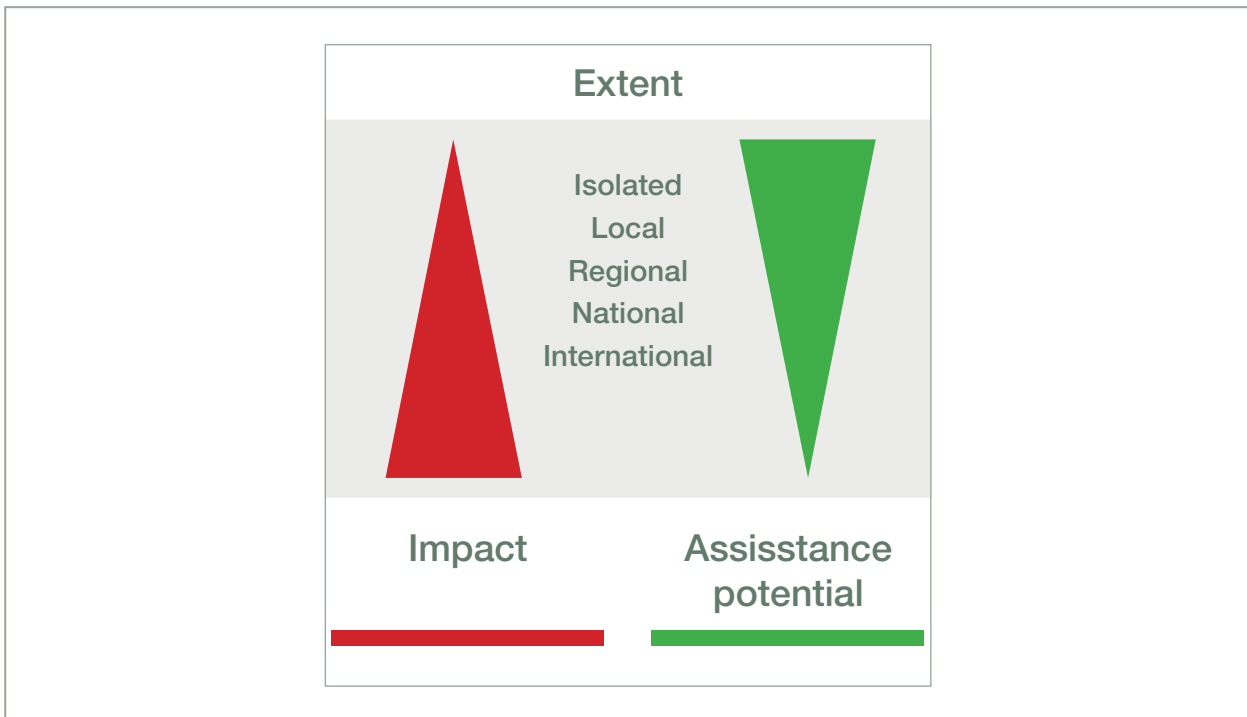


Figure 31: Decrease in assistance potential with increasing spatial extent of the power failure

Source: Hartl 2012.

"Authorities, rescue services and police are themselves critical infrastructures and extremely dependent on the power supply."

(Reichenbach et al. 2008, p. 23)

6.3.1 Dependency

Dependency of emergency services on the power supply

1. Which of the named emergency services are dependent on the power supply for their functional capability? This means, which organisations cannot execute their key tasks – at least at times – without power?

The processor should specify the relevant emergency services and check individually to see whether they have already evaluated their dependency on the power grid and other infrastructures. Which central tasks can be maintained and for how long?

- District administrator (of a Land) or mayor⁴⁴
- Police
- Fire brigade
- THW (German governmental disaster relief organisation)
- Relief organisations:
 - Arbeiter-Samariter-Bund (ASB)
 - Deutsche Lebens-Rettungs-Gesellschaft (DLRG)
 - Deutsches Rotes Kreuz (DRK)
 - Johanniter-Unfall-Hilfe (JUH)
 - Malteser Hilfsdienst (MHD)
- Other

The relevant control centres in particular should have an emergency power supply. A regular test under real conditions, i. e. complete disconnection from the grid is important in order to ensure operational capability in case of a disaster.

The various emergency services should also check and record which external resources can be obtained e. g. from higher-level organisations. If emergency power devices are available their location and the availability of suitable devices in relation to the potential need should be analysed.

However, in general it must be borne in mind that the power failure may extend beyond the region so that neighbouring municipalities may not be in a position to provide assistance. In this context the local authority should discuss whether other players such as businesses/institutions and the public should be informed of the limits of civil protection so that they are motivated to look after themselves. At the same time coping strategies using the municipalities own resources should be planned.

Notes

(e. g. regarding contact persons, contact details or required actions)

⁴⁴ The emergency services include the disaster prevention authorities which at other levels comprise the ministries responsible for disaster management or senate administration and may also include the middle level of government administration in the Länder. The emergency power supply for these authorities will not be investigated further in this guideline.

Alerting staff during power failures

2. How do staff make the journey between work and home?
- Public transport → It is possible that public transport will no longer function due to the power failure.
 - Passenger vehicle → It should be remembered that petrol pumps which are not supplied with emergency power can fail and staff may no longer be able to refuel.
 - On foot / by bicycle → These members of staff will presumably have the least difficulties in reaching their place of work. You should check what proportion of the staff can reach their place of work on foot or by bicycle in order to get an overview of the potential availability of staff during an incident.
3. Is alerting staff organised (does every member of staff know if and when he/she should go to work in case of a disaster)?
- Yes.
 - No. → You should ensure that members of staff know how they will be alerted in case of an incident and when they should go on duty. If all available staff appear on duty at the start, then the availability of staff during a failure which lasts for a longer period may pose a problem.

Notes

(e. g. regarding contact persons, contact details or required actions)

6.3.2 Level of preparation

Availability of emergency power within the emergency services

1. Which of the named dependent emergency service organisations have an emergency power supply?
- District administrator (of a Land) or mayor
 - Police
 - Fire brigade
 - THW (German governmental disaster relief organisation)
 - Relief organisations:
 - Arbeiter-Samariter-Bund (ASB)
 - Deutsche Lebens-Rettungs-Gesellschaft (DLRG)
 - Deutsches Rotes Kreuz (DRK)
 - Johanniter-Unfall-Hilfe (JUH)
 - Malteser Hilfsdienst (MHD)
 - Other

Communication during a power failure

2. Do the relevant emergency services have satellite communication?
 - Yes. → It must be borne in mind that, during a power failure, this will only function if it is not reliant on a functioning Internet (Voice over IP technology).
 - No. → You should consider setting up satellite communication for emergency situations and keep relevant contact details in paper form.
3. Are the relevant contact details, for example of other emergency services or the CI operators, known and available in paper form?
 - Yes.
 - No. → You should exchange the contact details of the satellite communication devices with the other emergency services and keep them in paper form as electronic folders may not function during a power failure.

It should also be checked whether satellite communication is compatible between the various parties and whether communication is possible without dialing a public network. The public telephone network can break down during a power failure so that satellite communication may also not work if this is dependent on a dial-up.

4. Can a radio link e. g. using emergency vehicles be established as an alternative?
 - Yes.
 - No. → You should develop alternative means of communication such as radio links in case a power failure occurs.
5. Do the relevant plans take account of adequate fuel for emergency vehicles and whether they can be refuelled?
 - Yes.
 - No. → Remember that the availability of fuel may be limited as pumps at filling stations may not work. The radio link might therefore only be able to be maintained for a few hours.
6. Is there contact to regional emergency or amateur radio groups?
 - Yes.
 - No. → You should contact the relevant groups as they could assist the communication of the authorities and emergency services during incidents⁴⁵.

Notes

(e. g. regarding contact persons, contact details or required actions)

⁴⁵ See e. g. <http://www.notfunk-deutschland.de/index.html>.

7. *Have you planned a non-technical form of communication as a last resort?*
- Yes.
 - No. → You should include the use of messengers and megaphones etc. in your planning in case other means of communication are no longer available.
8. *Are typewriters and carbon paper available which could be used for the dissemination of information?*
- Yes.
 - No. → You should consider keeping appropriate equipment to hand in case of a disaster.

Operation plans and definition of tasks

9. *Are staff functions during a power failure clearly defined? Have key personnel been identified?*
- Yes.
 - No. → It should be ensured that staff know their tasks during a disaster.
10. *Have lists been drawn up of the tasks to be completed within certain time frames in the event of a power failure?*
- Yes.
 - No. → You should draw up appropriate lists of tasks in order to reduce response times.
11. *Can staff spend the night in their place of work if necessary?*
- Yes.
 - No. → You should consider setting up sleeping accommodation. If this is not possible, thought should be given to how this could be improvised at short notice.
12. *Would it be possible for staff to be accommodated in the offices of a neighbouring local authority to work from there, if this is not affected?*
- Yes. → It should be ensured that employees can also reach the relevant place of work in the event of an incident.
 - No. → You should discuss whether appropriate cooperation with the neighbouring local authority is possible.

Staff catering

13. *Are there food and drink supplies available for staff?*
- Yes.
 - No. → In the event of a disaster, it may also be difficult to obtain food and drink since refrigeration systems, sale points or cash machines may no longer work. A check should therefore be made as to whether it is possible to cater for staff.

Notes

(e. g. regarding contact persons, contact details or required actions)

14. How long will food and drink supplies last?

- < 1 day
- 1 – 2 days
- > 2 days
- Don't know. → You should check how long you can supply staff with food and drinking water during a disaster as they may not be able to get supplies themselves. Food shops may not be open and the drinking water supply could also fail. If necessary, staff should be made aware that their employer may not be able to guarantee to cater for them (see also e. g. Section V-A-3 to V-A-6 of the *Krisenhandbuch Stromausrfall*).

Notes

(e. g. regarding contact persons, contact details or required actions)

Fuel requirement and alternative fuel supply

"Fuel and emergency generators can very quickly become bottleneck resources"

(Reichenbach et al. 2008, p. 25)

15. Is the fuel requirement of the emergency services in your own municipality known?

- Yes.
- No. → Information about the fuel requirement can be included in the precautionary planning and lead to an adjustment of the supplies to actual requirements. If this is not possible for technical or financial reasons, the analysis of requirements and supplies at least allows a realistic assessment of the possible consequences of a power failure and enables quantities to be prioritised.

16. Does the municipality have filling stations with emergency power?

- Yes.
- No. → You should consider whether it is possible to install an emergency powered filling station in your municipality. Cooperation with filling station operators is suggested here. It is also worth considering in advance whether emergency powering of particular filling stations could be done by the fire brigade, for instance, or whether generators could be obtained. Creating an awareness amongst the operators may also be of help.

17. Do all emergency services have a list in paper form of the filling stations with emergency power?

- Yes.
- No. → You should compile a list and send it to all the relevant emergency services.

18. Is fuel distribution from emergency powered filling stations organised?

- Yes. → You should check whether this can also be guaranteed.
- No. → You should check whether policies for prioritising supply are in place and can be adhered to in the event of an incident.

Notes

(e. g. regarding contact persons, contact details or required actions)

It can be difficult in this respect that

"Emergency generators [...] are not part of the standard equipment of a filling station, so that the relevant equipment may not be present or only in isolated cases."

(Reichenbach et al. 2008, Appendix 1.2, p. 2)

6.4 Vulnerability of critical infrastructure operators and businesses to power failures

As already stated above, cooperation between the municipalities and the operators of the supply grids is particularly important for reducing municipal vulnerability to power failures. Besides the electricity supply, this includes amongst others water supply and disposal companies, gas supplier, transport service providers and information and telecommunication companies. In this respect it is important to know which precautionary measures may have been taken by the various operators in order to prevent possible cascading effects triggered by a power failure. At the same time it should be clarified what assistance from the emergency services the operators are relying on (potentially mistakenly) and which measures could be taken in terms of prevention.

Besides the operators of CIs, the analysis should include those businesses and factories which are particularly dependent on the power supply due to their production processes (esp. manufacturing industries) e. g. paper mills. Possible preventative measures and potential limitations in the capacity of the emergency services in the event of a larger power failure should be discussed jointly. The specified relevant operators and businesses should be taken into account or represented when organising round table discussions in the municipality and included in any scenarios or exercises. The following questions can be seen as a first step in assessing the vulnerability to power failures.

6.4.1 Dependency

Taking account of power failure scenarios for CI operators and businesses and assessment of potential economic consequences

- Have the operators of the electricity supply and the businesses located in the municipality examined the power failure scenario and checked whether a power cut would affect their own operation?*
 - Yes.
 - No. → You should check whether the operators/businesses have taken account of the possible losses which may arise and whether they expect assistance from the emergency services.
- In the event of an interruption to the power supply, could (larger) economic losses arise?*
 - Yes. → It should be checked whether these could be prevented by appropriate precautionary measures.
 - No. → The operators/businesses should be encouraged to assess potential losses and to take preventative measures if possible.

Notes

(e. g. regarding contact persons, contact details or required actions)

Taking account of cascading effects

3. *Has consideration been given to the possibility of cascading effects in other sectors of the infrastructure meaning that information and communication systems, the water supply and waste water disposal and the transport system could break down?*
- Yes.
 - No. → Cascading effects should be included in the analysis of potential impacts on the operations in order to develop action strategies.
4. *Are operators/businesses aware of their role in connection with possible cascading effects?*
- Yes.
 - No. → Operators of other critical infrastructures can prevent or at least delay the occurrence of cascading effects by appropriate precautionary measures. They should adopt their own suitably comprehensive precautionary measures as far as possible.

Bearing in mind the potential economic losses, it can be worthwhile to implement an emergency power supply for individual companies. Useful information on setting up and operating an emergency power supply can be found in the relevant guideline by the BBK (2008a).

Notes

(e. g. regarding contact persons, contact details or required actions)

6.4.2 Level of preparation

Availability of an energy power supply

1. *Do the operators/businesses have an emergency power supply?*
- Yes.
 - No. → The potential limitations of the emergency services should be pointed out so that the business/operator can take the appropriate precautionary measures themselves if necessary.

Personnel and organisational preparation

2. *Have the operators/businesses made preparations for a potential power failure in terms of organisation and personnel? For example, are staff functions clearly defined in case of a disaster? Have key personnel been defined?*
- Yes. → What measures can be applied to other operators or businesses?
 - No. → Besides technical preventative measures, employee responsibilities during a disaster should be clearly defined.

3. *Does the operator/business have a functioning disaster management plan?*

- Yes. → It should be remembered that regular exercises should be carried out for this.
- No. → A functioning disaster management plan should be established.

Notes

(e. g. regarding contact persons, contact details or required actions)

Further reading

As described at the start, the checklist is intended to raise awareness in the municipalities about the topic of power failures. However, municipalities should

also deal more thoroughly with the topic and with appropriate plans. The following publications can be used for this:

In the old Federal Republic of Germany, rural and urban districts compiled what are known as *Orts- oder Kreisbeschreibungen* (local or district descriptions). However, the Federal Government did not issue any legal regulations which made these compulsory. The descriptions were intended to form a working basis and decision tool for the chief administrative officer of a rural or urban district in times of crisis. They contained information on the structure of the district, the resources and the options for assisting people in need. After the end of the Cold War these district descriptions were no longer maintained in many places. Nevertheless, the old documents still provide a structured beginning for emergency planning. The local or district descriptions may still exist in your area of responsibility and can be used as a basis for compiling the reference files. The guideline for making an inventory can be obtained online from the BBK.

Richtlinie zur Bestandsaufnahme von 1975 (guideline for making an inventory from 1975)

http://fis.bbk.bund.de/aDISWeb/app;jsessionid=4F6AAE9B3D87204DB5F94A613AED2F40?service=aDISAsset/POOLBMSD_44002300_28A47E00/ZLAK_HTMLGL_1&sp=S%24OTPDF_1&sp=SMT00000001&requestCount=5

Richtlinie zur Bestandsaufnahme von 1981 (guideline for making an inventory 1981)

http://fis.bbk.bund.de/aDISWeb/app;jsessionid=4F6AAE9B3D87204DB5F94A613AED2F40?service=aDISAsset/POOLBMSD_44002300_28A47E00/ZLAK_HTMLGL_1&sp=S%24OTPDF_1&sp=SMT00000001&requestCount=4



Figure 32: Crisis Management Guideline „Blackout“

The handbook „Krisenhandbuch Stromausfall“ in its full version describes in detail various relevant areas in connection with power failures. For example it examines the legal basis and the power supply as such with its effects on other infrastructures. The handbook also covers numerous wide-ranging planning aids including the preparation for and coping with the disaster of a power failure:

Innenministerium Baden-Württemberg und Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) (Eds.) (2010): Handbook "Krisenmanagement Stromausfall", short version. Available at:

[http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/PublikationenKritis/Krisenhandbuch_Stromausfall_Kurzfassung_pdf?__blob=publicationFile \(10.01.2013\)](http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/PublikationenKritis/Krisenhandbuch_Stromausfall_Kurzfassung_pdf?__blob=publicationFile (10.01.2013))

The report by the German Federal Government (document 17/5672) "Gefährdung und Verletzbarkeit moderner Gesellschaften – am Beispiel eines großräumigen und langandauernden Ausfalls der Stromversorgung" analyses the effects of a power failure on a range of dependent infrastructure services such as transport, water supply and the health service which would be adversely affected by the failure of the power supply, and presents options for coping with this and requirements for action:

Deutscher Bundestag (2011): Drucksache 17/5672 – TA-Projekt: Gefährdung und Verletzbarkeit moderner Gesellschaften – am Beispiel eines großräumigen langandauernden Ausfalls der Stromversorgung. Ausschuss für Bildung, Forschung und Technikfolgenabschätzung. Berlin. Available at:

<http://dipbt.bundestag.de/dip21/btd/17/056/1705672.pdf> (10.01.2013).

The report by the German Federal Government is based on the report by the Büro für Technikfolgen-Abschätzung (Office of Technology Assessment) (TAB), which analyses the effects of power failures on selected critical infrastructures and behaviour-related consequences in order to demonstrate coping options and requirements for action:

M. und U. Riehm (2010): Gefährdung und Verletzbarkeit moderner Gesellschaften – am Beispiel eines großräumigen Ausfalls der Stromversorgung, Büro für Technikfolgen-Abschätzung beim Deutschen Bundestag, Arbeitsbericht Nr. 141. Available at:

<http://www.tab-beim-bundestag.de/de/pdf/publikationen/berichte/TAB-Arbeitsbericht-ab141.pdf> (25.03.2013).

Petermann, T., Bradke, H., Lüllmann, A., Poetzsch,



Figure 33: Assessing Vulnerability to Flood Events at a Community Level

Information regarding the vulnerability assessment of electricity and water supply to flooding are compiled in the guideline "Abschätzung der Verwundbarkeit gegenüber Hochwasserereignissen auf kommunaler Ebene" (Assessing Vulnerability to Flood Events at a Community Level):

Birkmann, J., Dech, S., Gähler, M., Krings, S., Kühling, W., Meisel, K., Roth, A., Schieritz, A., Taubenböck, H., Vollmer, M., Welle, T., Wolfertz, J., Wurm, M. und H. Zwenzner (2010a): Abschätzung der Verwundbarkeit gegenüber Hochwasserereignissen auf kommunaler Ebene. Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK). Praxis im Bevölkerungsschutz, Band 4. Bonn. Available via:

http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Praxis_Bevoelkerungsschutz/Band_4_Hochwasser-Kom-Ebene.pdf?__blob=publicationFile (10.01.2013).

Methods for carrying out a risk analysis can be obtained from the relevant BBK publication:

Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) (2010a): Methode für die Risikoanalyse im Bevölkerungsschutz, Wissenschaftsforum, Band 8. Bonn. Available at:

http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Wissenschaftsforum/Bd8_Methode-Risikoanalyse-BS.pdf?__blob=publicationFile (17.04.2013).

Information on dealing with power failures and the appropriate precautionary options for the public are presented in the flyer „Stromausfall – Vorsorge und Selbsthilfe“:

Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) (2008c): Stromausfall. Vorsorge und Selbsthilfe. Bonn. Available at:

http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Broschueren_Flyer/Flyer_Stromausfall.pdf?__blob=publicationFile (18.02.2013).

The Federal Ministry of the Interior (BMI) has published two Leitfäden für Unternehmen und Behörden (guidelines for companies and authorities) which deal with the protection of critical infrastructures and crisis communication:

Bundesministerium des Innern (BMI) (2011): Schutz Kritischer Infrastrukturen – Risiko- und Krisenmanagement: Leitfaden für Unternehmen und Behörden, Berlin. Available at:

http://www.bmi.bund.de/SharedDocs/Downloads/DE/Broschueren/2008/Leitfaden_Schutz_kritischer_Infrastrukturen.pdf?__blob=publicationFile (17.04.2013).

Bundesministerium des Innern (BMI) (2008): Krisenkommunikation: Leitfaden für Behörden und Unternehmen, Berlin. Available at:

http://www.bmi.bund.de/SharedDocs/Downloads/DE/Broschueren/2008/Krisenkommunikation.pdf?__blob=publicationFile (17.04.2013).

Further information on disaster management can be found in the brochure „Bevölkerungsschutz in Deutschland“ and on carrying out exercises in „Leitfaden für strategische Krisenmanagement-Übungen“ by the BBK. In addition, the fire brigade Regulation 100 (FwDV 100) can be used for further information on management and control during operations.

Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) (2010b): Bevölkerungsschutz in Deutschland, Kompetenz im Bevölkerungsschutz. Bonn. Available at:

http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Broschueren_Flyer/Faltblatt_bevoelkerungsschutz.pdf?__blob=publicationFile (17.04.2013).

BBK (2011c): Leitfaden für strategische Krisenmanagement-Übungen, Bonn. Available at:

http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Broschueren_Flyer/Leitf_KM_Uebung.pdf?__blob=publicationFile (15.04.2013).

FwDV 100 dated March 1999, available at:

http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/FIS/DownloadsRechtundVorschriften/Volltext_Fw_Dv/FwDV%20100.pdf?__blob=publicationFile (17.04.2013)

VII. Chapter

Developing measures at municipal level

7.1 Using the assessment results

After applying the assessment methods described, a broad range of information and data on the spatial distribution and the values of the vulnerability criteria at municipal level is made available. The results of the assessments can provide the underlying information for developing and implementing measures to reduce the vulnerability of the municipality, the population and critical infrastructures to heat waves and heavy rainfall events.

There are basically three options for dealing with the results of the assessment to be chosen depending on the problem, the desired level of protection, the effort required, as well as the resources and options available in the municipality:

1. The vulnerability can be accepted
2. The exposure can be reduced (e. g. taking into account the level of exposure when building new facilities for socio-economic service infrastructures, or town planning measures to reduce the urban heat island effect).
3. The susceptibility can be reduced or the coping capacity can be increased (e. g. by creating redundant CI components or developing information materials in other languages than German to ease the preparation of those who do not speak the official language) at various levels (population, emergency services and operators/businesses).

The results of the vulnerability assessment therefore provide a basis for improving preventive planning and risk management. The measures should be developed and implemented by the local authority in close cooperation with operators of critical infrastructures and the emergency services (e. g. fire and rescue services). Suggestions on possible measures were given in the discussions of the individual aspects of vulnerability and should be put into practice on the basis of the results and specific circumstances in the municipality.

The vulnerability assessment also enables setting priorities in implementing the measures, on the one

hand by thematic areas, such as identifying particularly vulnerable people or components, and on the other hand spatially, i. e. identifying particularly vulnerable areas in the municipality.

Considering the ongoing change in the climate and the actual findings on the future development of climatic extreme events respectively, the development of protective measures as well as of information and awareness-raising activities for the public and other stakeholders should be seen as continuous processes which have to be constantly adapted. It is therefore advisable to carry out vulnerability assessments regularly.

Overall, the guideline follows up on the publication “Abschätzung der Verwundbarkeit gegenüber Hochwasserereignissen auf kommunaler Ebene” (Assessing Vulnerability to Flood Events at a Community Level) (Birkmann et al. 2010a) and analyses the vulnerability of Critical Infrastructure and the population towards additional natural hazards (heat waves and heavy rainfall). With the aid of the developed vulnerability assessment methods, municipalities are enabled to integrate the respective aspects into civil protection activities as well as to develop preventive strategies towards climate change-related effects. The vulnerability analysis builds a comprehensive basis for the development of measures and – with respect to the different components and aspects analysed – emphasizes the need for interdisciplinary and multi-stakeholders cooperation.

The second assessment step which analyses the effects of an electricity supply failure is based on existing research (see for example IM Ba-Wü und BBK 2010) but focuses on the need for communication and cooperation within municipalities and the consideration of different degrees of dependency of certain population groups or socio-economic service infrastructures. The exchange of information and contacts among municipal organizations and institutions as well as with the public can highly mitigate the impact of power supply failures and thus has to be integrated into the vulnerability reduction towards extreme events.

7.2 Additional information material

As civil protection will be pushed to its limits in the event of an area-wide power failure and many measures in the case of heavy rainfall and heat waves can only be carried out at an individual level, businesses and institutions as well as the public must be involved in the planning process. This can be achieved by e. g. information and awareness rising campaigns which provide information and lessons from past events and their consequences in order to provide recommendations for action. Active learning and further training can support the awareness-raising process.

Measures can be taken based on the vulnerability assessments for which approaches and examples have already been suggested at various points in the guideline. Some of these refer to *best practice* examples which have been applied by partners. The recommendations should be seen as examples and are not exhaustive. At the same time, there are already plenty of guidelines and leaflets on relevant measures for heat waves, heavy rainfall and power failure for various stakeholders. These can be used by the municipalities so that the effort for developing and implementing measures can be kept as small as possible.

The following are some relevant leaflets provided by the BBK:

Basisschutz für Katastrophenschutz und Hilfsorganisationen (Basic protection for emergency services and relief organisations):

http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/PublikationenKritis/Basis-schutz_HiOrg.pdf?__blob=publicationFile

The guideline aims to reduce the vulnerabilities of disaster management and relief organisations to extreme natural events, technical failure and criminal action. It includes structural, organisational, personal, and technical standard safety measures.

Schutz Kritischer Infrastrukturen – Risiko- und Krisenmanagement, Leitfaden für Unternehmen und Behörden (Critical Infrastructure Protection – Risk and Crisis Management, Guideline for enterprises and public administration):

http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/PublikationenKritis/Leitfaden_Schutz-Kritis.pdf?__blob=publicationFile

The guideline presents a management plan for those facilities which are designated as critical infrastructures by the authorities. The plan supports the operators of critical infrastructures in developing a systematic assessment of risks, the implementation of derived preventive measures, and the effective and efficient handling of emergency situations.

Schutz Kritischer Infrastruktur: Risikomanagement im Krankenhaus (Critical Infrastructure Protection – Hospital Risk Management):

http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Praxis_Bevoelkerung-schutz/Band_2_Leitfaden_Risikomanagm_Krankenh_Kritis.pdf?__blob=publicationFile

This brochure addresses authorities responsible for hospitals and individuals in charge in the management, medical, and technical supervision of the areas of safety, alert planning, emergency and utility management and infrastructure provision. It outlines the most important steps in a risk management process and provides practical recommendations for action for the relevant staff members.

Empfehlungen zur Sicherheit von Gebäuden (Recommendations for building safety):

http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Broschueren_Flyer/Flyer_Gebaeudesicherheit.pdf?__blob=publicationFile

The leaflet describes preventive protection measures of new and old buildings to natural hazards.

Hitze - Vorsorge und Selbsthilfe (Heat - Preparation and self-help):

http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Broschueren_Flyer/Flyer_Hitze.pdf?__blob=publicationFile

The leaflet provides information on early warning for heat waves and the relevant precautionary measures.

Stromausfall - Vorsorge und Selbsthilfe (Power failure - Preparation and self-help):

http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Broschueren_Flyer/Flyer_Stromausfall.pdf?__blob=publicationFile

The flyer gives information on the likelihood of power failures in Germany and on the relevant preparation options for the public.

Für den Notfall vorgesorgt (Prepared for emergencies):

http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Broschueren_Flyer/Brosch_FdN.pdf?__blob=publicationFile

The brochure contains information on general precautionary measures for fires, accidents and power failures. Besides useful tips on behaviour, it includes lists of objects which every household should have in reserve.

In relation to adapting to climate change there is also a series of activities by the Federal Government which are of interest to the local authorities. For example, there are a number of institutions which are responsible for the compilation and communication of information on adapting to climate change (cf. Bundesregierung 2011). These include the German Meteorological Service (DWD), the Competence Centre on Climate Impacts and Adaptation (KomPass) at the German Federal Environment Agency, the Climate Service Center (CSC), the Potsdam Institute for Advanced Sustainability Studies e.V. and the Strategische Behördenallianz (strategic alliance of public authorities). Local authorities can obtain further information from these institutions on developing appropriate measures. Further, the Climate Alliance⁴⁶ or ICLEI – Local Governments for Sustainability⁴⁷ can act as a platform for exchange with other local authorities.

⁴⁶ <http://www.klimabuendnis.org/home.html?&L=1>

⁴⁷ <http://resilient-cities.iclei.org/>

Bibliography

- Adnot, J., Grignon-Masse, L., Legendre, S., Marchio, D., Nermond, G., Rahim, S., Riviere, P., Andre, P., Detroux, L., Lebrun, J., L'Hoest, J., Teodorose, V., Alexandre, J. L., Sa, E., Benke, G., Bogner, T., Conroy, A., Hitchin, R., Pout, C., Thorpe, W. and S. Karatasou (2008): Preparatory study on the environmental performance of residential room conditioning appliances (airco and ventilation) - Economic and Market analysis. Tech. rep., The European Commission.
- Akbari, H., Pomerantz, M. and H. Taha (2001): Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas. In: *Solar Energy*, .70, 295–310.
- Alexander, L.V., Zhang, X., Peterson, T.C., Caesar, J., Gleason, B., Klein Tank, A., Haylock, M., Collins, D., Trewin, B., Rahim, F., Tagipour, A., Kumar, K.R., Revadekar, J., Griffiths, G., Vincent, L., Stephenson, D.B., Burn, J., Agiular, E., Brunet, M., Taylor, M., New, M., Zhai, P., Rusticucci, M. and J.L. Vasquez-Aguirre (2006): Global observed changes in daily climate extremes of temperature and precipitation. In: *Journal of Geophysical Research – Atmospheres*, 111(5), DOI: 10.1029/2005JD006290.
- Allebrodt, B. and K. Sponholz (2008). *Nach dem Unwetter von Dortmund – Jahrbundertregen oder Folge des Klimawandels?* Nachricht vom 29.07.2008. Available at: <http://www.derwesten.de/nachrichten/im-westen/Jahrhundertregen-oder-Folge-des-Klimawandels-id521076.html> (25.11.2011).
- Aniello, C., Morgan, K., Busbey, A. and L. Newland (1995): Mapping micro-urban heat islands using Landsat™ and a GIS. In: *Computers & Geosciences*, 21(8), 965-9.
- Applegate, W. B., Runyan, J. W., Brasfield, L., Williams, M. L., Konigsberg, C. and C. Fouche, (1981). Analysis of the 1980 heat wave in Memphis. *Journal of the American Geriatrics Society*, 29, 337-342.
- Barredo, J. I. (2007): Major flood disasters in Europe: 1950-2005. In: *Natural Hazards*, 42(1), 125-48.
- Bartels, H., Malitz, G. and S. Asmus (1997): Starkniederschlagshöhe für Deutschland: KOSTRA. Deutscher Wetterdienst (DWD), Offenbach.
- Birkmann, J. (2004): Monitoring und Controlling einer nachhaltigen Raumentwicklung – Indikatoren als Werkzeuge im Planungsprozess. In: *Regio Spezial 2*. Dortmund.
- Birkmann, J. (2006): Measuring vulnerability to promote disaster-resilient societies: Conceptual frameworks and definitions. In: J. Birkmann (Ed.): *Measuring Vulnerability to Natural Hazards – Towards Disaster Resilient Societies*, Tokyo.
- Birkmann, J. (2011): First- and second-order adaptation to natural hazards and extreme events in the context of climate change. In: *Natural Hazards*, Vol. 58, 811 – 840.
- Birkmann, J. (2013): Measuring vulnerability to promote disaster-resilient societies: Conceptual frameworks and definitions. In: J. Birkmann (Ed.): *Measuring Vulnerability to Natural Hazards – Towards Disaster Resilient Societies*, 2. Edition, Tokyo, 9-54.
- Birkmann, J., Dech, S., Gähler, M., Krings, S., Kühling, W., Meisel, K., Roth, A., Schieritz, A., Taubenböck, H., Vollmer, M., Welle, T., Wolfertz, J., Wurm, M. and H. Zwenzner (2010a): Abschätzung der Verwundbarkeit gegenüber Hochwasserereignissen auf kommunaler Ebene. Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK). Praxis im Bevölkerungsschutz, Band 4. Bonn. Available at: http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Praxis_Bevoelkerungsschutz/Band_4_Hochwasser-Kom-Ebene.pdf?__blob=publicationFile (10.01.2013).
- Birkmann, J.; Vollmer, M. and J. Wolfertz (2010b): Abschätzung der Verwundbarkeit der Bevölkerung gegenüber Hochwasserereignissen. In: Birkmann, J.; Dech, S.; Gähler, M.; Krings, S.; Kühling, W.; Meisel, K.; Roth, A.; Schieritz, A.; Taubenböck, H.; Vollmer, M.; Welle, T.; Wolfertz, J.; Wurm, M. and H. Zwenzner (Hrsg.): *Abschätzung der Verwundbarkeit gegenüber*

- Hochwasserereignissen auf kommunaler Ebene. Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK). Praxis im Bevölkerungsschutz, Band 4. Bonn, 48-93. Available at: http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Praxis_Bevoelkerungsschutz/Band_4_Hochwasser-Kom-Ebene.pdf?__blob=publicationFile (10.01.2013).*
- Blättner, B., Heckenhahn, M., Georgy, S., Grewe, H.A. and S. Kupski (2010): Wohngebiete mit hitzeabhängigen Gesundheitsrisiken ermitteln – Soziodemografische und klimatische Kartierung als Planungsinstrument gezielter Prävention. In: *Bundesgesundheitsblatt*, 53, 75-81.
- Böhm, H.-R., Kemper, T. and R. Riechel (2011): Anpassung an die Folgen des Klimawandels. Handlungskonzept für das Gersprenz-Einzugsgebiet, Technische Universität Darmstadt, Institut IWAR, KLARA-Net, Darmstadt. Available at: <http://www.klara-net.de/home/downloads> (15.01.13).
- Bornstein, R. D. (1968): Observations of the urban heat island effect in New York City. In: *Journal of Applied Meteorology*, 7, 575–582.
- Bouchama, A., Dehbi, M., Mohamed, G., Matthies, F., Shoukri, M. and B. Menne (2007): Prognostic Factors in Heat Wave Related Deaths: A Meta-analysis. *Archives of Internal Medicine*, 167/20, 2170-2176.
- Büchel, M. von (2008): *Hochwasser-Versammlung: Bürger schildern die Katastrophe*. Available at <http://www.ruhrnachrichten.de/lokales/dortmund/westen/Hochwasser-Versammlung-Buerger-schildern-die-Katastrophe;art2577,393913>, Article of 28.10.2008 (25.11.2011).
- Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) (2007): Basisschutz für Katastrophenschutz und Hilfsorganisationen. Bonn. Available at: http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/PublikationenKritis/Basisschutz_HiOrg.pdf?__blob=publicationFile (18.02.2013).
- Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) (2008a): Leitfaden für die Einrichtung und den Betrieb einer Notstromversorgung in Behörden und anderen wichtigen öffentlichen Einrichtungen. Bonn.
- Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) (2008b): Schutz Kritischer Infrastruktur: Risikomanagement im Krankenhaus. Bonn. Available at: http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Praxis_Bevoelkerungsschutz/Band_2_Leitfaden_Risikomanagm_Krankenh_Kritis.pdf?__blob=publicationFile (10.01.2013).
- Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) (2008c): Stromausfall. Vorsorge und Selbsthilfe. Bonn. Available at: http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Broschueren_Flyer/Flyer_Stromausfall.pdf?__blob=publicationFile (18.02.2013).
- Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) (2009): Hitze – Vorsorge und Selbsthilfe. Bonn. Available at: http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Broschueren_Flyer/Flyer_Hitze.pdf?__blob=publicationFile (10.01.2013).
- Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) (2010a): Methode für die Risikoanalyse im Bevölkerungsschutz, Wissenschaftsforum, Band 8. Bonn. Available at: http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Wissenschaftsforum/Bd8_Methode-Risikoanalyse-BS.pdf?__blob=publicationFile (17.04.2013).
- Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) (2010b): Bevölkerungsschutz in Deutschland, Kompetenz im Bevölkerungsschutz. Bonn. Available at: http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Broschueren_Flyer/Faltblatt_bevoelkerungsschutz.pdf?__blob=publicationFile (17.04.2013).

- Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) (2011a): Empfehlung zur Sicherheit von Gebäuden. Bonn. Available at: http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Broschueren_Flyer/Flyer_Gebaeudesicherheit.pdf?__blob=publicationFile (10.01.2013).
- Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) (2011b): Schutz Kritischer Infrastrukturen – Risiko- und Krisenmanagement Leitfaden für Unternehmen und Behörden. Bonn. Available at: http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/PublikationenKritis/Leitfaden_Schutz-Kritis.pdf?__blob=publicationFile (10.01.2013).
- Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) (2011c): Leitfaden für strategische Krisenmanagement-Übungen, Bonn. Available at: http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Broschueren_Flyer/Leitf_KM_Uebung.pdf?__blob=publicationFile (15.04.2013).
- Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) (2012a): Klimawandel – Herausforderung für den Bevölkerungsschutz. Praxis im Bevölkerungsschutz Band 5. Bonn.
- Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) (2012b): Behörden und Organisationen mit Sicherheitsaufgaben (BOS). Available at: http://www.bbk.bund.de/DE/Servicefunktionen/Glossar/_function/glossar.html?lv2=1899366&lv3=1948880.
- Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) (2012c): Für den Notfall vorgesorgt. Bonn. Available at: http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Broschueren_Flyer/Brosch_FdN.pdf?__blob=publicationFile (10.01.2013).
- Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) (2013): Sturzfluten. Bonn. Available at: http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Broschueren_Flyer/Flyer_Sturzfluten.pdf?__blob=publicationFile (13.08.2013).
- Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) und Deutscher Städtetag (DST) (Hrsg.) (2010): Drei Ebenen, ein Ziel: Bevölkerungsschutz – gemeinsame Aufgabe von Bund, Ländern und Kommunen. Bonn. Available at: http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Broschueren_Flyer/DreiEbenen-einZiel.html (18.02.2013).
- Bundesamt für Güterverkehr (BAG) (2003): Marktbeobachtungen, Herbst 2003. Köln.
- Bundesamt für Sicherheit in der Informationstechnik (BSI) und Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) (2013): Kritische Infrastrukturen – Definition und Übersicht. Available at: http://www.kritis.bund.de/SubSites/Kritis/DE/Einfuehrung/einfuehrung_node.html (12.08.2013).
- Bundesanstalt für Gewässerkunde (BfG) (2006): Niedrigwasserperiode 2003 in Deutschland. Ursachen – Wirkungen – Folgen. Koblenz.
- Bundesministerium des Innern (BMI) (2009): Nationale Strategie zum Schutz Kritischer Infrastrukturen (KRITIS-Strategie). Available at: http://www.bmi.bund.de/SharedDocs/Downloads/DE/Themen/Sicherheit/SicherheitAllgemein/kritis.pdf?__blob=publicationFile (10.01.2013).
- Bundesnetzagentur (2006): Untersuchungsbericht über die Versorgungsstörungen im Netzgebiet des RWE im Münsterland vom 25.11.2005 durch die Bundesnetzagentur für Elektrizität, Gas, Telekommunikation, Post und Eisenbahnen. Available at: http://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/BNetzA/Sachgebiete/Energie/Sonderthemen/Versorgungsstoerung-Muensterland05/UntersuchungsberichtId6420pdf.pdf?__blob=publicationFile (12.01.2012).
- Bundesnetzagentur (2012): Monitoringbericht 2011. Available at: http://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Allgemeines/Bundesnetzagentur/Publikationen/Berichte/2011/MonitoringBericht2011.pdf?__blob=publicationFile&v=2 (27.05.2013).

- Bundesregierung (2008): Deutsche Anpassungsstrategie an den Klimawandel. Berlin. Available at: http://www.bmu.de/files/pdfs/allgemein/application/pdf/das_gesamt_bf.pdf (10.01.2013).
- Bundesregierung (2011): Aktionsplan Anpassung der Deutschen Anpassungsstrategie an den Klimawandel, Berlin.
- Cieminski, K. and A. Brede (2008): Unwetter setzt Marten unter Wasser. Available at: <http://www.ruhrnachrichten.de/lokales/dortmund/westen/Unwetter-setzt-Marten-unter-Wasser;art2577,317260> (25.11.2011).
- Clark, G., Moser, S., Ratick, S., Dow, K., Meyer, W., Emani, S., Jin, W., Kasperson, J. X., Kasperson, R. E. and H. E. Schwarz (1998): Assessing the vulnerability of coastal communities to extreme storms: The case of Revere, MA, USA. In: *Mitigation and Adaptation Strategies for Global Change*, 3, 59–82.
- Corburn, J. (2009): Cities, Climate Change and Urban Heat Island Mitigation: Localising Global Environmental Science. In: *Urban Studies*, 46, 413–427.
- Coumou, D. and S. Rahmstorf (2012): A decade of weather extremes. In: *Nature Climate Change*, 2, 491–496.
- Coumou, D., Robinson, A. and S. Rahmstorf (2013): Global increase in record-breaking monthly mean temperatures. In: *Climatic Change*, 118(3–4), 771–782.
- Creutin, J.D., Borga, M., Lutoff, C., Scolobig, A., Ruin, I. and L. Créton-Cazanave (2009): Catchment dynamics and social response during flash flood: the potential of radar rainfall monitoring for warning procedures. In: *Meteorological Applications*, 16(1), 115–125.
- Curriero, F., Heiner, K., Samet, J., Zeger, S., Strug, L., and J. Patz (2002): Temperature and mortality in 11 cities of the eastern United States. In: *American Journal of Epidemiology*, 155, 80–87.
- Cutter, S.L., Boruff, B.J. and W.L. Shirley (2003): Social vulnerability to environmental hazards. In: *Social Science Quarterly*, 84, 242–261.
- Cutter, S.L., Mitchell, J.T. and M.S. Scott (2000): Revealing the vulnerability of people and places: A case study of Georgetown County, South Carolina. In: *Annals of the Association of American Geographers*, 90, 713–737.
- Danks, D.M., Webb, D.W. and J. Allen (2004): Heat illness in infants and young children – a study of 47 cases. In: *Wilderness and Environmental Medicine*, 15, 293–300.
- Deutscher Bundestag (2011): Drucksache 17/5672 – TA-Projekt: Gefährdung und Verletzbarkeit moderner Gesellschaften – am Beispiel eines großräumigen langandauernden Ausfalls der Stromversorgung. Ausschuss für Bildung, Forschung und Technikfolgenabschätzung. Berlin. Available at: <http://dipbt.bundestag.de/dip21/btd/17/056/1705672.pdf> (10.01.2013).
- Deutscher Städtetag (2012): Positionspapier Anpassung an den Klimawandel - Empfehlungen und Maßnahmen der Städte. Cologne. Available at: http://www.staedtetag.de/imperia/md/content/dst/positionspapier_klimawandel_juni_2012.pdf (10.01.2013).
- Deutscher Wetterdienst (DWD) (2010): DWD Wetterlexikon: Starkregen. Available at: <http://www.deutscher-wetterdienst.de/lexikon/index.htm?ID=S&DAT=Starkregen> (19.02.2013).
- Deutscher Wetterdienst (DWD) (2013): Starkregen (Starkniederschlag), Wetterlexikon. Available at: http://www.dwd.de/bvbw/appmanager/bvbw/dwdwwwDesktop?_nfpb=true&_pageLabel=dwdwww_menu2_wetterlexikon&_nfls=false (28.02.2013).
- Diaz, J., Garcia, R., Velazquez de Castro, F., Hernández, E., López, C. and A. Otero (2002): Effects of extremely hot days on people older than 65 years in Seville (Spain) from 1986 to 1997. In: *International Journal of Biometeorology*, 46/3, 145–149.

- Divya, K. C. and J. Østergaard (2009): Battery Energy Storage Technology for power systems-An overview. In: *Electric Power Systems Research*, 79, 511-520.
- dpa (2008): Wetterchaos in Dortmund. Available at: <http://www.ruhrnachrichten.de/lokales/dortmund/Wetterchaos-in-Dortmund;art930,317299>, Message of 27.07 2008 (25.11.2011).
- dpa/lnw (2008): *Millionenschaden durch Juliunwetter in Dortmund*. Available at: <http://www.ruhrnachrichten.de/nachrichten/region/nordrhein-westfalen/art5192,330041>, Nachricht vom 12. 08 2008 (25.11.2011).
- Ebertz, M. (2012): Die Auswirkungen des Sturmtiefs Kyrill auf den Kreis Siegen-Wittgenstein, Präsentation im Rahmen des Workshops "Operative Vorbereitung auf Stromausfälle" am 20. November 2012, Fraunhofer, FIT, Sankt Augustin. Available at: <http://www.fit.fraunhofer.de/content/dam/fit/de/documents/ebertz.pdf> (23.04.2013).
- Ellis, F. P., Prince, H. P., Lovatt, G. and R. M. Whittington (1980): Mortality and morbidity in Birmingham during the 1976 heatwave. *The Quarterly Journal of Medicine*, 49, 1-8.
- Fekete, A. (2011): Common Criteria for the Assessment of Critical Infrastructures. In: *International Journal of Disaster Risk Science*, 2 (1), 15-24
- Füssel, H.-M. and R.J.T. Klein (2006): Climate change vulnerability assessments: an evolution of conceptual thinking. In: *Climatic Change*, 75(3), 301-329.
- Gallego, F. J. (2010): A population density grid of the European Union. In: *Population and Environment*, 31, 460-473.
- Gaume, E., Livet, M., Desbordes, M. and J. P. Ville-neuve (2004): Hydrological analysis of the river Aude, France, flash flood on 12 and 13 November 1999. In: *Journal of Hydrology*, 286 (1-4), 135-154.
- Geenen E.M. (2010): Bevölkerungsverhalten und Möglichkeiten des Krisenmanagements und Katastrophenschutzmanagements in multikulturellen Gesellschaften, Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK), Forschung im Bevölkerungsschutz, Band 11. Bonn. Available at: http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/PublikationenForschung/FiB_Band11.pdf?__blob=publicationFile (26.02.13).
- Gill, S. E., Handley, J. F., Ennos, A. R. and S. Pauleit (2007): Adapting Cities for Climate Change: The Role of the Green Infrastructure. In: *Built Environment*, 33 (1), 115-133.
- Golden, J. S. (2004): The built environment induced urban heat island effect in rapidly urbanizing arid regions – a sustainable urban engineering complexity. In: *Environmental Sciences*, 1(4), 321-349.
- Greenberg, J. H., Bromberg, J., Reed, C. M., Gustafson, T. L. and R. A. Beauchamp (1983): The epidemiology of heat-related deaths, Texas-1950, 1970-1979. In: *American Journal of Public Health*, 73, 805-807.
- Grünewald, U. (2009). *Zur Entstehung und Verlauf der extremen Niederschlags-Ablauf-Ereignisse am 26.07.2008 im Stadtgebiet von Dortmund*. Available at: http://gruene-luedo.de/download/gutachten_neu.pdf (25.11.2011).
- Hadjipaschalis, I., Poullikkas, A. and V. Efthimiou (2009): Overview of current and future energy storage technologies for electric power applications. In: *Renewable and Sustainable Energy Reviews*, 13 (6-7), 1513-1522.
- Hamburg Wasser (Hrsg.) (2012): Wie schütze ich mein Haus vor Starkregenfolgen? Ein Leitfaden für Hauseigentümer, Bauherren und Planer. Hamburg. Available at: <http://www.hamburg.de/contentblob/3540740/data/leitfaden-starkregen.pdf> (10.01.2013).
- Hartl, P. (2012): Einsatzplanung der Feuerwehr Köln für einen großflächigen Stromausfall. Präsentation im Rahmen der Veranstaltung „Operative Vorbereitung auf Stromausfälle“ des Fraunhofer-Institut für Angewandte Informationstechnik FIT. Available at: <http://www.fit.fraunhofer.de/de/events/stromausfall.html> (21.02.2013).

- Henschel, A., Burton, L. L., Margolis, L. and J. E. Smith (1969): An analysis of the heat deaths in St. Louis during July, 1966. In: *American Journal of Public Health*, 59, 2232-2242.
- ICSU-LAC (2010): Science for a better life: Developing regional scientific programs in priority areas for Latin America and the Caribbean. Vol 2, Understanding and Managing Risk Associated with Natural Hazards: An Integrated Scientific Approach in Latin America and the Caribbean [Cardona, O.D., Bertoni, J.C., Gibbs, A., Hermelin, M. and A. Lavell (Eds.)]. ICSU Regional Office for Latin America and the Caribbean, Rio de Janeiro, Brazil.
- Ingenieurbüro Reinhard Beck GmbH & Co. KG (2012): internal communication December 2012.
- Innenministerium Baden-Württemberg (IM Ba-Wü) and Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) (Hrsg.) (2010): Handbuch „Krisenmanagement Stromausfall“, Kurzfassung. Available at: http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/PublikationenKritis/Krisenhandbuch_Stromausfall_Kurzfassung.pdf?__blob=publicationFile (10.01.2013).
- Institut Wohnen und Umwelt (IWU) (2005): Deutsche Gebäudetypologie. Systematik und Datensätze. Available at: http://www.iwu.de/fileadmin/user_upload/dateien/energie/klima_altbau/Gebaeudetypologie_Deutschland.pdf (30.01.13).
- Institut Wohnen und Umwelt (IWU) (2011): Deutsche Gebäudetypologie. Beispielhafte Maßnahmen zur Verbesserung der Energieeffizienz von typischen Wohngebäuden. Available at: http://www.building-typology.eu/downloads/public/docs/brochure/DE_TABULA_TypologyBrochure_IWU.pdf (30.01.13).
- Intergovernmental Panel on Climate Change (IPCC) (2012): Managing the Risks of Extreme Event and Disasters to advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor und P.M. Midgley (Eds.). Cambridge University Press, Cambridge, UK and New York, NY, USA.
- International Risk Governance Council (IRGC) (2006): White Paper on Managing and Reducing Social Vulnerabilities from Coupled Critical Infrastructures. Châtelaine.
- Johnson, H., Kovats, R.S., McGregor, G., Stedman, J., Gibbs, M., Walton, H., Cook, L. and E. Black (2005): The impact of the 2003 heat wave on mortality and hospital admissions in England. In: *Health Statistics Quarterly*, 25, 6-11.
- Jones, T. S., Liang, A. P., Kilbourne, E. M., Griffin, M., Patriarca, P., Wassilak, S., Mullan, R.J., Herrick, R.F., Donnell, H.D., Choi, K. and S. B. Tacker (1982): Morbidity and mortality associated with the July 1980 heat wave in St Louis and Kansas City, Mo. In: *Journal of the American Medical Association*, 247, 3327-3331.
- Jonkman, S.N. (2005): Global perspectives on loss of human life caused by floods. In: *Natural Hazards*, 34, 151-175.
- Kaźmierczak, A. and G. Cavan (2011): Surface water flooding risk to urban communities: Analysis of vulnerability, hazard and exposure. In: *Landscape and Urban Planning*, 103, 185 – 197.
- Kelsch, M., Coporali, E. and L. G. Lanza (2001): Hydrometeorology of Flash Floods. In: Grunfest, E. and J. Handmer (Eds.): *Coping With Flash Floods*, NATO Sciences Series, 2. Environmental Security, 77, 19 – 36.
- Kilbourne, E., Cho, K., Jones, T. and S. Thacker (1982): Risk factors for heat stroke: a case-control study. In: *Journal of the American Medical Association*, 247, 3332-3336.
- Kjellstrom, T. (2009): Climate change, direct heat exposure, health and well-being in low and middle income countries. In: *Global Health Action*, 2, 1-3.

- Klein, I. (2011): Abschätzung physischer Vulnerabilität gegenüber Hochwasser – Das Potential der Fernerkundung. Diplomarbeit Universität Augsburg, 2011.
- Koppe, C., Jendritzky, G. and G. Pfaff (2004): Die Auswirkungen der Hitzewelle 2003 auf die Gesundheit. In: Deutscher Wetterdienst (Hrsg.): *Klimastatusbericht 2003*. Offenbach. 152-162.
- Kovats, R.S. and Ebi, K. L. (2006). Heatwaves and public health in Europe. In: *European Journal of Public Health*, 16/6, 592-599.
- Kovats, R.S. and S. Hajat (2008): Heat Stress and Public Health: A Critical Review. In: *Annual Review of Public Health*, 29, 41-55.
- Krings, S. (2010): Verwundbarkeitsassessment der Strom- und Trinkwasserversorgung gegenüber Hochwasserereignissen. In: Birkmann, J.; Dech, S.; Gähler, M.; Krings, S.; Kühling, W.; Meisel, K.; Roth, A.; Schieritz, A.; Taubenböck, H.; Vollmer, M.; Welle, T.; Wolfertz, J.; Wurm, M. and H. Zwenzer (Hrsg.): *Abschätzung der Verwundbarkeit gegenüber Hochwasserereignissen auf kommunaler Ebene*. Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK). Praxis im Bevölkerungsschutz, Band 4. Bonn, 21-47. Available at: http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Praxis_Bevoelkerungsschutz/Band_4_Hochwasser-Kom-Ebene.pdf?__blob=publicationFile (10.01.2013).
- Kröger, W. (2008): Critical infrastructures at risk: A need for a new conceptual approach and extended analytical tools. In: *Reliability Engineering and System Safety*, 93, 1781-1787.
- Kron, W. (2005): Flood Risk = Hazard*Values*Vulnerability. International Water Resources Association. In: *Water International*, 30 (1), 58-68.
- Kropp, J., Holsten, A., Lissner, T., Roithmeier, O., Hattermann, F., Huang, S., Rock, J., Wechsung, F., Lüttger, A., Pompe, S., Kühn, I., Costa, L., Steinhäuser, M., Walther, C., Klaus, M., Ritchie, S. and M. Metzger (2009): Klimawandel in Nordrhein-Westfalen - Regionale Abschätzung der Anfälligkeit ausgewählter Sektoren, Abschlussbericht des Potsdam-Instituts für Klimafolgenforschung (PIK) für das Ministerium für Umwelt und Naturschutz, Landwirtschaft und Verbraucherschutz Nordrhein-Westfalen (MUNLV).
- Kumar, R. and S.C. Kaushik (2005): Performance evaluation of green roof and shading for thermal protection of buildings". In: *Building and Environment*, 40, 1505 – 1511.
- Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen (LANUV NRW) (2013): Klimawandel in Stadtentwässerung und Stadtentwicklung, TU Kaiserslautern, Dr. Pecher AG und hydro & meteo GmbH & Co.KG Wasserwirtschaft. Available at: http://www.lanuv.nrw.de/wasser/abwasser/KISS_Bericht.pdf (13.08.2013).
- Landkreis Karlsruhe (2006a): Was ist bei großer Hitze zu beachten?. Available at: http://www.landkreis-karlsruhe.de/media/custom/1076_139_1.PDF (10.01.2013).
- Landkreis Karlsruhe (2006b): Was ist bei großer Hitze zu beachten? II. Available at: http://www.landkreis-karlsruhe.de/media/custom/1076_138_1.PDF (10.01.2013).
- Landtag von Baden-Württemberg (2003): Ausnahmegenehmigung für die Einleitung von Kühlwasser durch Kraftwerke in Rhein und Neckar im Sommer 2003, Drucksache 13/2365. Available at: http://www9.landtag-bw.de/wp13/drucksachen/2000/13_2365_d.pdf.
- Lecomte, D. and D. Penanster de (2004): People living in Paris, dead during the August 2003 heat-wave, and examined in Medicolegal Institute. In: *Bulletin de l' Academie Nationale de Medicine*, 188, 459-470.
- Linhoff, B. (2008). Jahrhundert-Regen legt Stadt lahm. Nachricht vom 27. 07 2008. Available at: <http://www.ruhrnachrichten.de/lokales/dortmund/-Jahrhundert-Regen-legt-Stadtlahm;art930,317471> (25.11.2011).

- Lissner, T., Holsten, A., Walther, C. and J. P. Kropp (2012): Towards sectoral and standardised vulnerability assessments: the example of heatwave impacts on human health. In: *Climatic Change*, 112 (3-4), 687-708.
- Lönker, O. (2003): Hitzefrei für Atomstrom. In: *Neue Energie*, 9, 22-23.
- Lorenz, F. L. (2010): Kritische Infrastrukturen aus Sicht der Bevölkerung. In: *Schriftenreihe Forschungsforum Öffentliche Sicherheit*, 3, FU Berlin. Berlin.
- Marchi, L., Borga, M., Preciso, E. and E. Gaume (2010): Characterization of selected extreme flash floods in Europe and implications for flood risk management. In: *Journal of Hydrology*, 394, 118-133.
- McGeehin, M. A. und M. Mirabelli (2001): The potential impacts of climate variability and change on temperature-related morbidity and mortality in the United States. In: *Environmental Health Perspectives*, 109, 185-189.
- McGregor, G. R., Fero, C. A. T. and B. D. Stephenson (2005): Projected changes in extreme weather and climate events in Europe. In: *Extreme Weather Events and Public Health Responses*, 1, 13-23.
- Medina-Ramón, M. and J. Schwartz (2007): Temperature, Temperature Extremes, and Mortality: A Study of Acclimatization and Effect Modification in 50 United States Cities. In: *Occupational and Environmental Medicine*, 64/12, 827-833.
- Medina-Ramón, M., Zanobetti, A., Cavanagh, D. and J. Schwartz (2006). Extreme temperatures and mortality: assessing effect modification by personal characteristics and specific cause of death in a multi-city case only analysis. In: *Environmental Health Perspectives*, 114, 1331-1336.
- Memon, R.A., Leung, D.Y.C. and C.H. Liu (2008): A Review on the Generation, Determination and Mitigation of Urban Heat Island. In: *Journal of Environmental Sciences*, 20, 120-128.
- Ministerium für Umwelt und Naturschutz, Landwirtschaft und Verbraucherschutz des Landes Nordrhein-Westfalen (MUNLV) (2009): Anpassung an den Klimawandel – Eine Strategie für Nordrhein-Westfalen. Düsseldorf. Available at: http://www.umwelt.nrw.de/umwelt/pdf/klimawandel/Klimawandel_Anpassungsstrategie_Gesamt.pdf (10.01.2013).
- Ministerium für Umwelt und Naturschutz, Landwirtschaft und Verbraucherschutz des Landes Nordrhein-Westfalen (MUNLV) (2010): Handbuch Stadtklima: Maßnahmen und Handlungskonzepte für Städte und Ballungsräume zur Anpassung an den Klimawandel. Available at: http://www.umwelt.nrw.de/klima/pdf/handbuch_stadtklima.pdf (27.11.12).
- Mirchandani, H., McDonald, G., Hood, I. and C. Fonseca (1996): Heat-Related Deaths in Philadelphia-1993. In: *American Journal of Forensic Medicine & Pathology*, 17 (2), 106-108.
- Monstadt, J. (2008): Der räumliche Wandel der Stromversorgung und die Auswirkungen auf die Raum- und Infrastrukturplanung. In: Moss, T., Naumann, M. und M. Wissen (Eds.): *Infrastrukturnetze und Raumentwicklung*, Munich, 187-224.
- Montz, B. E. and E. Grunfest (2002): Flash flood mitigation: recommendations for research and applications. In: *Environmental Hazards*, 4, 15-22.
- Mücke, H.-G., Klasen, J., Schmoll, O. and R. Szewzyk (2009): *Gesundheitliche Anpassung an den Klimawandel*. UBA, Dessau-Roßlau.
- Nachbarschaftsverband Karlsruhe (NVK) (2011): Ökologische Tragfähigkeitsstudie für den Raum Karlsruhe. Karlsruhe.
- Naef, F., Scherrer, S. and A. Faeh (1998): Die Auswirkungen des Rückhaltevermögens natürlicher Einzugsgebiete bei extremen Niederschlagsereignissen auf die Größe extremer Hochwasser. In: *Abschlussbericht im Rahmen des Forschungsprogrammes „Klimaänderung und Naturkatastrophen“*, Nationales Forschungsprogramm 31. Zürich.

- Nakai, S., Itoh, T. and T. Morimoto (1999): Deaths from Heat Stroke in Japan: 1968-1994. In: *International Journal for Biometeorology*, 43/3, 124-127.
- O'Neill, M., Zanobetti, A. and J. Schwartz (2003): Modifiers of the temperature and mortality association in seven US cities. In: *American Journal of Epidemiology*, 175, 1074-1082.
- Olonscheck, M., Holsten, A. and J. Kropp (2011): Heating and cooling energy demand and related emissions of the German residential building stock under climate change. In: *Energy Policy*, 39(9), 4795-4806.
- Palomo, E. and D. Barrio (1998): Analysis of the green roofs cooling potential in buildings. In: *Energy and Buildings*, 27, 179-193.
- Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J. and C.E. Hanson (Eds.) (2007): Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
- Perry, C.A. (2000): Significant floods in the United States during the 20th Century – USGS measures a Century of Floods. Available at: <http://ks.water.usgs.gov/pubs/fact-sheets/fs.024-00.pdf>.
- Petermann, T., Bradke, H., Lüllmann, A., Poetzsch, M. and U. Riehm (2010): Gefährdung und Verletzbarkeit moderner Gesellschaften – am Beispiel eines großräumigen Ausfalls der Stromversorgung, Büro für Technikfolgen-Abschätzung beim Deutschen Bundestag, Arbeitsbericht Nr. 141. Available at: <http://www.tab-beim-bundestag.de/de/pdf/publikationen/berichte/TAB-Arbeitsbericht-ab141.pdf> (25.03.2013).
- Philadelphia Office of Emergency Management (2012): Excessive Heat. Available at: <http://oem.readyphiladelphia.org/Heat> (10.12.12).
- Ramin, B. and T. Svoboda (2009): Health of the Homeless and Climate Change. In: *Journal of Urban Health: Bulletin of the New York Academy of Medicine*, 86, 654-663.
- Rannow, S., Loibl, W., Greiving, S., Gruehn, D. and B. C. Meyer (2010): Potential impacts of climate change in Germany—identifying regional priorities for adaptation activities in spatial planning. In: *Landscape and Urban Planning*, 98, 160–171.
- Reichenbach, G., Wolff, H., Göbel, R. and S. Stokar von Neuforn (2008): Risiken und Herausforderungen für die öffentliche Sicherheit in Deutschland – Szenarien und Leitfragen. Grünbuch des Zukunftsforums Öffentliche Sicherheit. Berlin. Available at: <http://www.zukunftsforum-oeffentliche-sicherheit.de/downloads/index.html> (10.01.2013).
- Robert Koch Institut – RKI (2003): Epidemiologisches Bulletin. Aktuelle Daten und Informationen zu Infektionskrankheiten und Public Health. 19. September 2003/ Nr. 38.
- Rothstein, B., Müller, U., Greis, S., Scholten, A., Schulz, J. and E. Nilson (2008): Auswirkungen des Klimawandels auf die Elektrizitätsproduktion unter besonderer Berücksichtigung des Aspekts Wasser. In: *Forum für Hydrologie und Wasserwirtschaft*, Heft 24.06.2008, 193-214.
- Ruin, I., Creutin, J.-D., Anquetin, S. and C. Lutoff (2008): Human exposure to flash floods – Relation between flood parameters and human vulnerability during a storm of September 2002 in Southern France. In: *Journal of Hydrology* (2008) 361, 199-213.
- Schneiderbauer, S. and D. Ehrlich (2006): Social levels and hazard (in)dependence in determining vulnerability. In: J. Birkmann (Ed.): *Measuring Vulnerability to Natural Hazards – Towards Disaster Resilient Societies*, Tokyo.
- Schwartz, J. (2005). Who is sensitive to Extremes of Temperature? A case-only Analysis. *Epidemiology*, 16 (1), 67-72.
- Semenza, J.C., Rubin, C.H., Falter, K.H., Selanikio, J.D., Flanders, W.D., Howe, H.L. and J. L. Wilhelm (1996): Heat-related deaths during the July 1995 heat wave in Chicago. In: *New England Journal of Medicine*, 335(2), 84–90.

- Solecki, W.D., Rosenzweig, C., Parshall, L., Pope, G., Clark, M., Cox, J. and M. Wiencke (2005): Mitigation of the heat island effect in urban New Jersey. In: *Global Environmental Change Part B: Environmental Hazards*, 6, 39–49.
- Sperling, K., Hvelplund, F. and B. V. Mathiesen (2011): Centralisation and decentralisation in strategic municipal energy planning in Denmark. In: *Energy Policy*, 39, 1338-1351.
- Stadt Karlsruhe (2011): Hitzephylaxe. Available at: <http://www.karlsruhe.de/b3/soziales/personengruppen/senioren/seniorenwegweiser/unterstuetzung/sicherheit/hitzephylaxe.de> (10.01.2013).
- Stadt Köln (2011): Synthetische Klimafunktionskarte. Datengrundlage Prof. Kuttler et al., Universität Essen, Klimatologische Untersuchungen Köln, 1997. Available at: <http://www.stadt-koeln.de/mediaasset/content/pdf57/77.pdf> (10.01.2013).
- Stadt Köln (o.J.a): Sommerhitze. Available at: <http://www.stadt-koeln.de/3/gesundheit/sommerhitze/> (10.01.2013).
- Stadt Köln (o.J.b): Was tun bei Hitze? Informationen und Hinweise für Seniorinnen und Senioren, Kranke und Hilfebedürftige und deren Betreuerinnen und Betreuer. Available at: <http://www.stadt-koeln.de/mediaasset/content/pdf53/1-6.pdf> (10.01.2013).
- Steadman, R. G. (1984): A universal scale of apparent temperature. In: *Journal of Climate and Applied Meteorology*, 23, 1674–1687.
- Taubenböck, H., Wurm, M., Klein, I. and T. Esch (2011): Verwundbarkeitsanalyse urbaner Räume: Ableitung von Indikatoren aus multisensoralen Fernerkundungsdaten. In: Real Corp 2011 Konferenz.
- Technisches Hilfswerk (THW) (2005): Jahresrückblick 2005. Available at: http://www.thw.de/SharedDocs/Meldungen/DE/Ein-saetze/national/2005/12/meldung_011.html?docId=976042¬First=true (12.02.2012).
- Thywissen, K. (2006): Components of Risk – A Comparative Glossary. In: *Studies of the University: Research, Counsel, Education (SOURCE)*, 2.
- Union for the Co-ordination of Transmission of Electricity (UCTE) (2007): Final Report - System Disturbance on 4 November 2006. Brussel: Union for the Co-ordination of Transmission of Electricity.
- United Nations International Strategy for Disaster Reduction (UNISDR) (2009): Disaster Risk Reduction, 2009 UNISDR Terminology. Geneva. Available at: http://www.unisdr.org/files/7817_UNISDRTerminologyEnglish.pdf (10.01.2013).
- United States Environmental Protection Agency (EPA) (2006): Excessive Heat Events Guidebook. Washington.
- URBAS (2011): Ereignisdatenbank. Förderprogramm des BMBF: Risikomanagement extremer Hochwasserereignisse. Vorhersage und Management von Sturzfluten in urbanen Gebieten. Available at: http://www.urbanesturzfluten.de/ereignisdb/ereignisse/ereignisse_view (16.01.13).
- Vandentorren, S., Bretin, P., Zeghnoun, A., Mandereau-Bruno, L., Croisier, A., Cochet, C., Ribéron, J., Siberan, I., Declercq, B. and M. Ledrans (2006): August 2003 Heat Wave in France: Risk Factors for Death of Elderly People Living at Home. In: *European Journal of Public Health*, 16, 583-591.
- VDN (Verband der Netzbetreiber - VDN – e.V. beim VDEW; merged with the Bundesverband der Energie- und Wasserwirtschaft (BDEW) in 2007) (2007): DistributionCode 2007 - Regeln für den Zugang zu Verteilungsnetzen. Berlin.
- VKU (Verband kommunaler Unternehmen e.V.) & BDEW (Bundesverband der Energie- und Wasserwirtschaft e.V.) (2012): Praxis-Leitfaden für unterstützende Maßnahmen von Stromnetzbetreibern, 12. Oktober 2012, Berlin.
- Wilhelmi, O.V. and R.E. Morss (2012): Integrated analysis of societal vulnerability in an extreme precipitation event: A Fort Collins case study. In: *Environmental Science and Policy*, 26, 49-62.

- World Health Organization (WHO) (2009): Improving public health responses to extreme weather/heat-waves – EuroHEAT. Technical summary.
- Yaron, M. and S. Niermeyer (2004): Clinical Description of Heat Illness in Children, Melbourne, Australia – A Commentary. In: *Wilderness and Environmental Medicine*, 15, 291-292.
- Weichert, T. (2007): Der Personenbezug von Geodaten. In: *Datenschutz und Datensicherheit*, 31(1), 17 – 23.
- Wupperverband, Stadt Wuppertal und WSW Energie & Wasser AG (n.a.): "Nasse Füße" in Wuppertal!? Available at: [http://www.wupperverband.de/internet/mediendb.nsf/gfx/med_IWER-8RVKD2_511230/\\$file/Broschuere_Nasse_Fuesse_Wuppertal.pdf](http://www.wupperverband.de/internet/mediendb.nsf/gfx/med_IWER-8RVKD2_511230/$file/Broschuere_Nasse_Fuesse_Wuppertal.pdf) (13.08.2013).
- Zebisch, M., Grothmann, T., Schröter, D., Hasse, C., Fritsch, U. and W. Cramer (2005): Klimawandel in Deutschland: Vulnerabilität und Anpassungsstrategien klimasensitiver Systeme. UBA. In: *Climate Change*, 08/05. Available at: www.umweltdaten.de/publikationen/fpdf-l/2947.pdf (15.02.2013).

List of abbreviations

ALFF	Amt für Landwirtschaft, Flurneuordnung und Forsten (Agency for Agriculture, Land Consolidation Procedures and Forestry)
BAG	Bundesamt für Güterverkehr (Federal Office for Goods Transportation)
BauGB	Baugesetzbuch (German Federal Building Code)
BBK	Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (German Federal Office of Civil Protection and Disaster Assistance)
BfG	Bundesanstalt für Gewässerkunde (German Federal Institute of Hydrology)
BMI	Bundesministerium des Innern (German Federal Ministry of the Interior)
BMU	Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety)
BOS	Behörden und Organisationen mit Sicherheitsaufgaben (The emergency services)
CIs	Critical Infrastructures
CSC	Climate Service Center
Dena	Deutsche Energie-Agentur (German Energy Agency)
DHM	Digital elevation model
DKKV	Deutsches Komitee Katastrophenvorsorge e.V. (German Committee for Disaster Reduction)
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Centre)
DST	Deutscher Städtetag (German Association of Cities)
DWD	Deutscher Wetterdienst (German Meteorological Service)
EItSV	Verordnung zur Sicherung der Elektrizitätsversorgung in einer Versorgungskrise (Directive on securing the energy supply during a supply crisis)
EnEV	Verordnung über energiesparenden Wärmeschutz und energiesparende Anlagentechnik bei Gebäuden (Directive on energy-saving heat insulation and energy-saving installation engineering in buildings)
EnSIG	Gesetz zur Sicherung der Energieversorgung (Energy Security Act)
EnWG	Gesetz über die Elektrizitäts- und Gasversorgung (Energy Industry Act)
EPA	United States Environmental Protection Agency
EU	European Union

FH	Fachhochschule (University of Applied Sciences)
FSHG	Gesetz über den Feuerschutz und die Hilfeleistung (Law on fire prevention and assistance)
GIS	Geographic Information System
Hz	Hertz
IF Star	Innovationspreis der öffentlichen Versicherer für Feuerwehren (public insurance company innovation prize for fire brigades)
IPCC	Intergovernmental Panel on Climate Change
IRGC	International Risk Governance Council
KIBEX	Kritische Infrastrukturen und Bevölkerungsschutz im Kontext klimawandelbeeinflusster Extremwetterereignisse (Critical Infrastructures and civil protection in the context of climate change related extreme weather events)
KITA	Kindertagesstätte
KRITIS	Kritische Infrastruktur
LK	Landkreis (rural district)
LpB-Datenpunkte	Last-Pulse Boden-Datenpunkte
LST	Land surface temperature data
MODIS	Moderate-resolution Imaging Spectroradiometer
MUNLV	Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen (Ministry for Climate Protection, Environment, Agriculture, Nature Conservation and Consumer Protection of the German State of North Rhine-Westphalia)
NDVI	Normalized Difference Vegetation Index“ (also Normalized Density Vegetation Index)
NRW	North Rhine-Westphalia
NVK	Nachbarschaftsverband Karlsruhe (Neighbourhood Association City of Karlsruhe)
ÖPNV	Öffentlicher Personennahverkehr (Local public transport)
PIK	Potsdam-Institut für Klimafolgenforschung (Potsdam Institute for Climate Impact Research)
RKI	Robert Koch Institute

RWTH Aachen	RWTH Aachen University
SV	Stadtviertel
Trafo	Transformator
TSO	Transmission System Operator
UBA	Umweltbundesamt (German Federal Environment Agency)
UCTE	Union for the Co-ordination of Transmission of Electricity
ÜNB	Übertragungsnetzbetreiber
UHI	Urban Heat Island Effect
UN/ISDR	United Nations International Strategy for Disaster Reduction
UNU-EHS	United Nations University Institute for Environment and Human Security
VDEW	Verband der Elektrizitätswirtschaft e. V. (Association of the Power Industry); merged with the "Bundesverband der Energie- und Wasserwirtschaft (BDEW) (German Association of Energy and Water Industries) in 2007
VDN	chem. Verband der Netzbetreiber (VDN) (former Association of System Operators) – e.V. at the VDEW
WHO	World Health Organization

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