Metropolitan Region Ruhr

Area and climate information

Population	1,800,000
Population density	2,563 Citizen/km²
Area	680 km²
GRP	9,806
GRP/cap.	31,211
Engineering, chemical, service industry	

Essen and the Ruhr area

Essen, an industrial city with 583,000 inhabitants, is one of the major cities in the extended metropolitan area '*Ruhrgebiet*' (Ruhr area), an industrial and mining hotspot. The project area is the metropolitan Ruhr region with a population of 1.8 million citizens and an area of 680 km². It includes Mülheim an der Ruhr, Gelsenkirchen, Herne, Bochum, Oberhausen and Essen. With a total population of 5.1 million inhabitants and covering 4400 km², the Ruhr region is the largest German urban area. It is located east of the Rhine river in the state of North Rhine-Westphalia.

The history of the region is strongly tied to the development of the coal and steel industries in the 19th century (as of 1815: 220,000 inhabitants). The region's development reached its climax in 1967 with 5.7 million inhabitants and has been decreasing since due to the decline of the coal and steel industries. The mining activities resulted in land subsidence up to 25 m., posing major challenges to the natural and constructed drainage systems.

In 2010, the area adopted the '*Regionaler Flächennutzungsplan*' (Regional Zoning Plan Ruhr 2030), Germany's first regional zoning plan.[1] It is a joint planning activity between the six cities mentioned above. The plan pooled the urban planning of Essen and the five other cities in the '*Städteregion Ruhr*' (Metropolitan Region Ruhr). It is an example of the trend towards consensual, holistic planning in Germany.[2]

Expected Climate Change

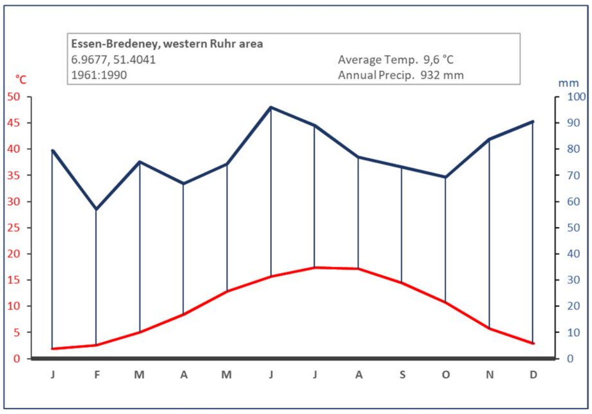

Figure 1: Climate characteristics in the Western Ruhr area: Warm summers, no dry season. Temperature increase since 1935: 1.7°C (Own figure based on data by DWD)

- Annual average temperature expected to rise by approximately 1.5 to 2 °C by 2050
- An increase in summer days from approximately 26 to 47 days
- An increase in heat days from approximately 10 to 22 days
- An increase of tropical nights by a factor of three
- Less precipitation in the summer, resulting in drier summers
- An increase in precipitation in winter

Direct climate impacts

- Due to the large urban agglomeration, the urban heat island is quite dominant, enhancing the effects of the temperature.
- Heavy rains might cause severe flooding if the urban infrastructure is not adapted accordingly.

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[1] Mielke, B., & Schürmann, T. (2006). Der Regionale Flächennutzungsplan im Ruhrgebiet.

[2] Planungsgemeinschaft Städteregion Ruhr. (2009). Textteil und Begründung zum Regionalen Flächennutzungsplan der Planungsgemeinschaft Städteregion Ruhr.

Adaptation measures to cope with climate change

The metropolitan Ruhr region was selected because of the joint 'Regional Zoning Plan' initiated by the aforementioned six cities. The plan is unique and requires legal justification. From a spatial planning perspective, it was a successful way to overcome the historical administrative boundaries. It allowed the government to look at the actual spatial and geographical structure of the area. The administrative entities do however still exist and the Regional Zoning Plan must fulfil each city's requirements. In this case, the adaptation is assessed thought the spatial planning lens.

Germany's spatial planning structure

In Germany, federal spatial planning is not very explicit. It is primarily text-oriented, while actual spatial planning is carried out by each state. Each state's planning department develops and enforces a 'Regional Plan' in cooperation with the relevant state cabinet, parliament committee or entire state parliament. After adopting the regional plan, the cities and districts develop a 'Zoning Plan'.

The metropolitan Ruhr area was the first to deviate from this scheme. The region instead combined the two plans in one 'Regional Zoning Plan' to address the interlinkages of the six participating cities on the metropolitan scale. An amendment of the North Rhine-Westphalia State Planning Law (2004/05) was the legal basis for this deviation from the norm. To clarify the approach, the relevant justification and public administrative guidance was documented in a special publication.[3] The plan, which covers a previously non-existent spatial unit, was designed using different administrative and spatial sources.

The federal spatial planning law of 2008 explicitly included the topic of climate change. The Regional Zoning Plan followed accordingly in 2010. This was essential, since the Plan would determine the region's adaptation options for a significant period of time. The main component of the Plan was the '*Klimafunktionskarte*' (Climate Functional Map), which was based on a study published by the *Ruhrverband* (Ruhr Alliance). The Ruhr Alliance is the largest water utility alliance in North Rhine-Westphalia. It was founded in 2013 when the high water demands of the coal and steel industries created severe shortages. It is a 'public benefit' organisation that manages the 'common good water' in the Ruhr catchment.

Climate Functional Map

The goal of the Climate Functional Map (which serves air quality, urban climate and urban climate change) was to understand the climatic function of land use zones and sites. A factor analysis based on relief and settlement structure was used to identify similar climate zones '*Klimatope*'[4] ('climatopes'). These zones consisted of the following:

- Open space climate
- Forest climate
- Park climate
- Watercourse climate
- Residential settlement climate
- Industrial area climate

The zones were used to identify **climate-stress areas** and **climate-relief areas**. But unlike for air quality, there are no legally binding reference or threshold values that can be used for assessment. The objective was thus defined as follows:

- Potential stress must be identified at the 'climatopes' level in order to derive the need for action and planning
- Relief potential must be localised to maintain and promote favourable climatic conditions
- Stress and relief areas must be recognisable in terms of their climatic-ecological significance against the background of climate change[5]

As part of the Regional Spatial Plan, the Climate Functional Map ensures the mitigation of urban/metropolitan characteristics that enhance the effects of climate change. This refers specifically to urban heat islands and floods due to sealed surfaces, and is more likely when climate stress areas are climatologically linked to climate relief areas. In the case of heat islands, this happens when the relief area is on the windward side of the stress area.

By covering a broader area, the combined Regional Zoning Plan and Climate Functional Map provide more options to balance stress and relief areas. To an extent, they remove the mismatch of administrative boundaries and natural geographical structure. This creates opportunities, especially for

[3] Mielke, B., & Schürmann, T. (2006). Der Regionale Flächennutzungsplan im Ruhrgebiet.

[4] Artificial word formation created by "climate" + Greek *topos* 'place'. An equivalent could be "climatescape".

[5] Snowden, A., & Funk, D. (n.d.). Fachbeitrag zum Regionalplan der Metropole Ruhr „Klimaanpassung" Fachbeitrag zum Regionalplan der Metropole Ruhr „Klimaanpassung".

heavily urbanized areas, since 'climate change' is not the only action field of planning. Nevertheless, joint urban planning only works if all cities share a joint objective as well as the will to establish long-term cooperation.

Climate Functional Map

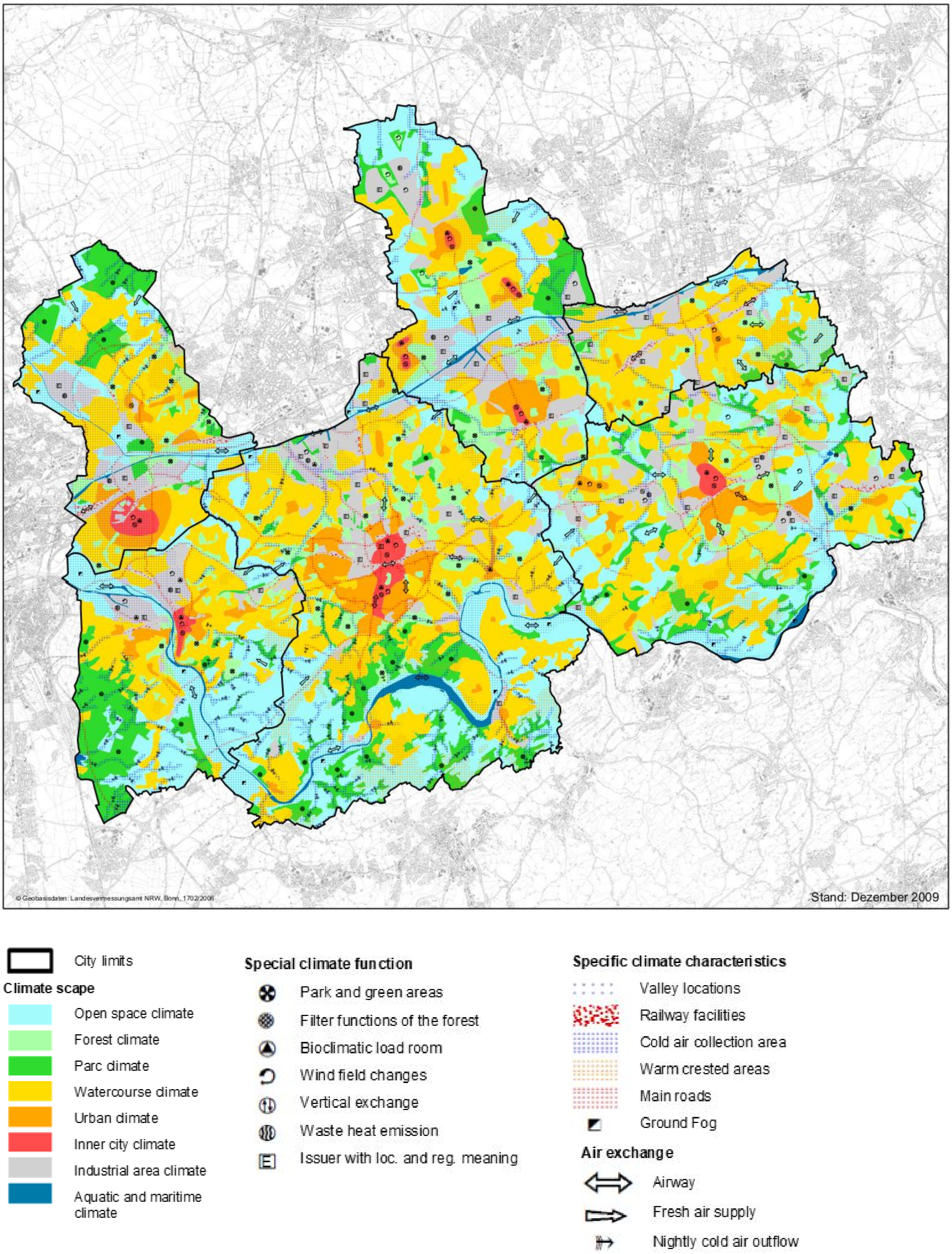

Figure 2 Climate Functional Map, part Regional Zoning Plan Ruhr 2030, source: http://www.staedteregion-ruhr-2030.de/cms/downloads1.html Anlage 1 Themenkarte 11

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Snowden, A., & Funk, D. (n.d.). Fachbeitrag zum Regionalplan der Metropole Ruhr „Klimaanpassung" Fachbeitrag zum Regionalplan der Metropole Ruhr „Klimaanpassung". Essen.

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Hamburg

State and climate information

Population	1,899,160
Population density	2,500 Citizen/km²
Area	755,220 km²
GRP	123 billion EUR/year
GRP/cap.	60,000 EUR/year

The city of Hamburg is one of Germany's 16 federal states. It is located between Schleswig-Holstein to the north and Lower Saxony to the south. With 1,899,160 inhabitants, Hamburg is the second most populous city in Germany. In total, over five million people live in the city's metropolitan region.[1] It is located about 100 km. upwards from the estuary of the Elbe river, where the two tributaries River Alster and River Bille merge. Despite being 100 km. from the North Sea coastline, Hamburg is home to Europe's third largest port.[2]

Hamburg is considered Northern Europe's most important centre for trade and economy. With a Gross Regional Product (GRP) of 123 billion Euro, Hamburg accounts for 3.6% of the German economic output. The port provides employment for over 155,000 people. The annual turnover of maritime economy lies at 9.5 billion Euro. Other key sectors include banking, heavy industry and aerospace industry, as well as media outlets, e-commerce and logistics. Each year, about 10,000 new companies are established or open new branches in Hamburg.[3] Furthermore, Hamburg is a major European science and research hub.

Expected climate change

In Hamburg, the mean expected change of temperature lies at +2.8°C.[4] Dry spells are also likely to increase. It remains unclear whether mean precipitation will change, but potential for heavy rains will increase slightly. Major climate stresses in Hamburg include:

- Heat waves
- Dry spells
- Heavy rain
- Storms
- Floods

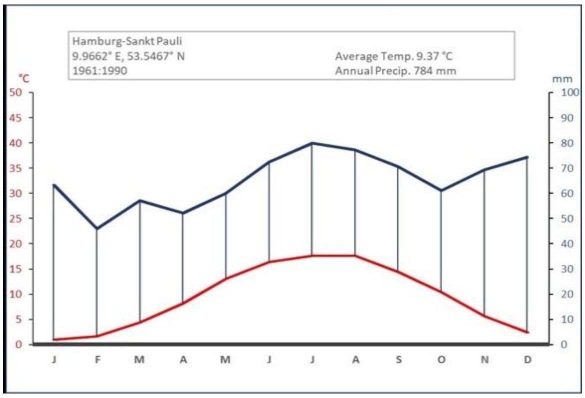

Figure 1: Climate characteristics in Hamburg: Maritime climate, influenced by its proximity to the coast. Temperature increase since 1881: 1.2°C (Own figure based on data from DWD)

Direct climate impacts

Due to its geographic position, Hamburg is particularly vulnerable to flooding. The risk of flash floods on an extremely convective day increases by up to 50% in large regions. As a port city, this has a direct impact on main economic infrastructure and other infrastructure located at the city's rivers and canals. As a large city with a high population density, the risk of heat wave is high.[5]

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[1] Wikipedia contributors. (2020). Hamburg.
[2] Hamburg Tourism. (n.d.). Elbeinfahrt - vom Meer in die City.
[3] Hamburg City Portal. (n.d.). Standortprofil: Wirtschaftszentrum.
[4] Norddeutschers Klimabüro. (n.d.). Metropolreg. Hamburg: Mögliche mittlere Änderung der durchschnittlichen Temperatur im Jahresmittel bis Ende des 21. Jahrhunderts (2071-2100) im Vergleich zu heute (1961-1990).
[5] European Climate Risk Typology. (n.d.). European Climate Risk Map.

Adaptation measures to cope with climate change

To address climate change, the Hamburg senate adopted a long-term adaptation strategy focused on continuously monitoring climate change and its impacts. It is based on an analysis of climate change and its impacts published in 2009. In 2013, the senate developed its adaptation strategy. An integrated climate plan followed in 2015. These steps laid the groundwork for the preventive measures needed to address climate change. The core areas of the strategy focus on floods, spatial planning, health and agriculture. They will be monitored through the following indicators:

- Inland floods (water infiltration, floods, warning systems, water temperature, oxygen concentration)
- Coastal floods (tidal conditions, fluvial flooding, wind intensity (wind fetch))
- Spatial planning with regards to dry spells and heat waves (tropical nights, hot days, dry spells)
- Health (heat warning systems, mosquito incidents)
- Agriculture (irrigation requirements, vegetation cycle)[6]

Adaptation activities include emergency warning for civil protection (including flood warning systems and risk-communication), health (including heat warnings) and developing heat resilient infrastructures, such as heat-resistant road surfaces.

Current activities focus on addressing flooding due to rising sea levels and increased risk of inland flooding of the Elbe and tributaries. Measures include strengthening the dykes and adapting early-warning and monitoring systems.

Another focus is the adaptation of rain infrastructure due to the increased risk of heat waves, dry spells and heavy rains. The *Regen Infrastruktur Anpassung* (*RISA*) (Rainwater Infrastructure Adaptation) programme addresses both risks. It is based on the 'sponge city' concept and emphasizes local, close-to-nature water management.[7] The sponge city concept responds to events of heavy rainfall as follows:

1) Avoid surface runoff at its source by increasing the infiltration, flow retention and storage capacity 'in situ'. This is mostly achieved through roof greening and micro ponds.
2) Effective and safe conveyance of the discharge, with decentralized temporary storage systems used to avoid high peak flows.
3) In areas where the two measures above are either not possible or insufficient, suitable measures such as temporary or permanent barriers or other constructive measures protect the urban infrastructure. In Hamburg, this is particularly necessary for energy infrastructure.

Furthermore, the programme uses interdisciplinary water management and planning instruments to bring the different public authorities and participation of the society together.

Green linkages

The '*Grün Vernetzen*' (Green Linkages) map is the basis for planning the green open areas in Hamburg. The map lays out the ecological aspects of the city's urban planning. By creating connections that the urban flora and fauna can use, the green spaces enhance the city's biodiversity and resilience. An additional measure, the 'greening' of urban houses, supports house owners in creating façade greening systems, vertical gardens and roof greening. By 2024, the municipality aims to exceed the 100 ha. threshold. This versatile adaptation measure creates recreational areas with high environmental quality and brings fresh air into the city. Plant evapotranspiration cools the neighbourhoods and significantly reduces direct runoff by heavy rains.

Hamburg Water Cycle

The Hamburg Water Cycle® is another innovative lighthouse project exploring sustainable and adapted uses of water.[8] Hamburg Wasser, the public water utility, recently introduced a radical new sewage concept in the Jenfelder Au, a former military area turned into a new city quarter. The concept breaks with the 'German standard' of decentralized wastewater treatment. It instead turns sewage treatment into an energy positive process by separating grey and black wastewater. Biogas is produced using the black wastewater to generate electricity and district heating. The grey water is treated and used to irrigate public parks. The project provides a holistic approach to both the energy supply and sanitation needs in urban areas.

[6] Hamburg City Portal (n.d.) Klimafolgenmonitoring Hamburg.

[7] Hamburg City Portal (n.d.) Anpassungsstrategie Hamburg.

[8] Hamburg Wasser (2019) Hamburg Water Cycle.

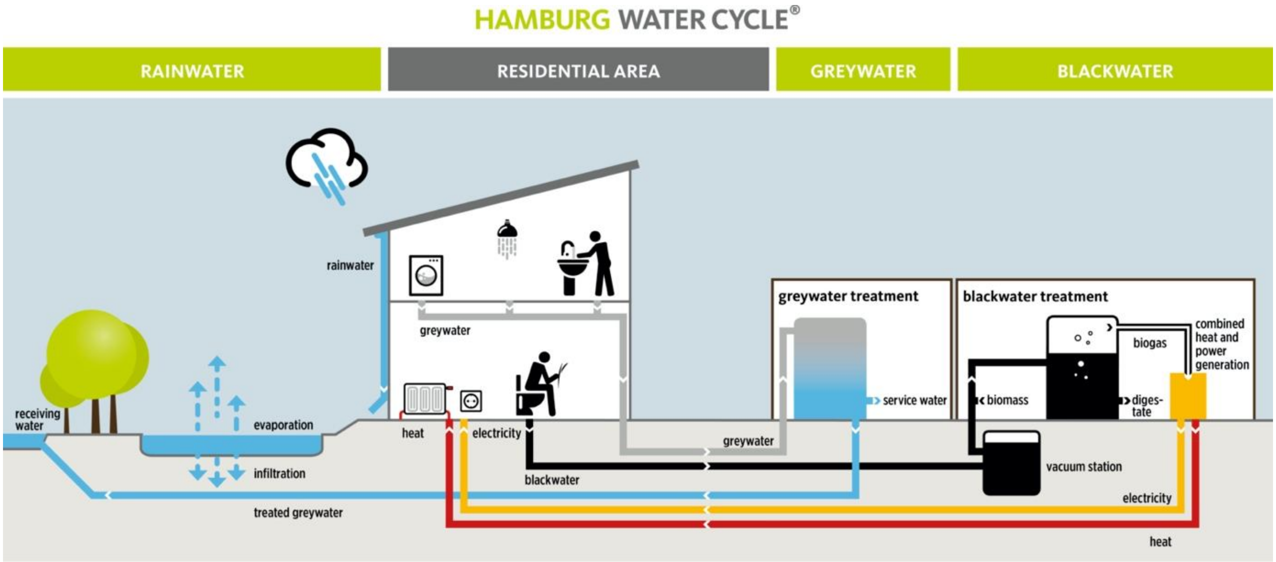

Figure 2: Hamburg Water Cycle (2019) Separation of domestic wastewater for energetic use [8].

Through this approach, the complimentary areas of water and energy infrastructure are interdependent and multifunctional. The approach protects water resources by reusing grey water locally, while simultaneously producing energy from black water. It closes the material cycles directly in the residential environment.

Through lighthouse projects like RISA, the Hamburg Water Cycle, the establishment of monitoring systems as well as close cooperation with research institutes, the city of Hamburg laid the foundation for its climate change adaptation.

Figure 3: Fermenter and energy storage at the Hamburg Wasser Depot at Jenfelder Au

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Wikipedia contributors. (2020, July 18). Hamburg. Retrieved August 1, 2020, from https://en.wikipedia.org/wiki/Hamburg

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Photo Hamburg Water Cycle: fotalia, HAMBURG WASSER, iStockphoto.

URL links:
https://www.hamburg.de/klimafolgen-monitoring
https://www.hamburgwatercycle.de/en/hamburg-water-cycler/

Saxony-Anhalt

State and climate information

Population	2,208,321
Pop. density	110 citizen/km²
Area	20,451.58 km²
GRP	64 billion EUR/year
GRP/cap.	29,000 EUR/year
99% of the enterprises are SME	

Saxony-Anhalt is a rural state with 80% of its population residing in the countryside. The only two urban agglomerations are Magdeburg and Halle/Saale. Before German reunification, the lignite, chemical and mechanical engineering industries were the main industrial sectors located around Halle/Saale, Merseburg and Bitterfeld. After 1990, they ceased to be competitive. While the chemical and engineering industries continue to operate, diversification has led to the growth of the food industry, tourism and service industry, as well as new technologies like bio-tech and renewable energy, which create economic opportunities. A historical structural deficit still remains.

Expected climate change

- The number of convectively extreme days will more than double by the end of the 21st century. Depending on the chosen scenario and climate model, they will be over 600 days per 30 years.
- The potential for heavy precipitation will increase slightly.
- The flash flood potential, including the risk of flash floods on an extremely convective day, will increase by up to 50% in large regions.
- There will be less rain in summer and more rain in winter.

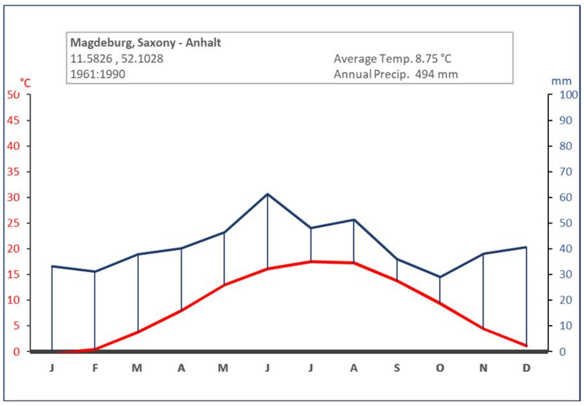

Figure 1: Climate characteristics in Magdeburg: Dry summers and cold winters. Temperature increase since 1881: 1,4°C (Own figure based on data from DWD)

Direct climate impacts

- Convective showers will increase, which will increase flash floods and direct runoffs.
- The climate-water balance will most likely decrease.
- There will be reduced groundwater recharge. The climate-water balance, which is already negative[1] will turn more negative. Water resources will be scarcer.

[1] Potsdam-Institut für Klimafolgenforschung. (2009). Klimawandel in Sachsen-Anhalt - Zusammenfassung. Potsdam

Adaptation measures to cope with climate change

Saxony-Anhalt was one of the first federal German states to work on adaptation. The working group on climate change (*AG Klima*) was launched by the state government in 2007. The group was composed of members of the administration, technical authorities, umbrella organisations and academics.

In 2010, Saxony-Anhalt published its first adaptation strategy and action plan. Two years later, the state released its first implementation report. In Feb. 2019, it issued the third update of the strategy.

Also in 2010, Sachsen-Anhalt released its State Development Plan (*Landesentwicklungsplan 2010*), comprising the goals and principles for the different spatial areas. The plan covered both climate protection and climate change with two-page sub-chapters. The sub-chapters included 11 principles but no goals. The Plan highlighted the overarching cross-sector characteristics but contained no cross-reference to the adaptation strategy or action plan. It did however describe potentially high-risk issues like flood protection or matters considered of high relevance for the "*Daseinsvorsorge*" (public service).

All plans follow the guidance of the DAS. The activity fields are structured accordingly. Due to site-specific exposition and importance, some fields have a more detailed, or more 'coarse' structure. Fishery, for example, is of no importance and is thus not mentioned. The following are discussed in detail:

- Education and science
- Culture
- Rural areas

Education and science

The education narrative is particularly noteworthy. Human-induced climate change will change our lives significantly, whether through the decarbonisation of our economy or through global warming beyond the 2° target. In either case, climate change will soon transform our world. We must thus change our lifestyles. Institutions of education are where the ecologic, economic and social implications of climate change are taught, and where the responsible use of resources must be developed and lived.

In addition to our own engagement, a voluntary change in our lifestyles requires awareness raising. We thus need comprehensive, deepened knowledge transfer and participatory methods that develop critical thinking, empathy and decision-making skills, enabling people to make their own decisions.

Since Saxony-Anhalt is primarily rural, the corresponding topics, such as forestry, are the most relevant for further studies. Most activities are integrated operationally. Many measures in the Adaptation Plan are rated 'continuously', which means that they are fully integrated into the provision of regular public services.

Please refer to the paragraph on the Leibniz Institute of Plant Genetics and Crop Plant Research (IPK) under 'Agriculture' as an example of scientific research.

Measures:

- Introduction of climate change in the curricula
- Teachers training on climate change
- Integration of 'global learning topics' like climate change in vocational training
- Introduction of climate change impacts on natural and technical infrastructure in the engineering curricula
- Bachelor studies in 'Green Engineering'

Culture

Saxony-Anhalt's cultural heritage is important for its regional identity. The main way to ensure cultural conservation is by securing the material legacy, including monuments, museums, historical archives and libraries, historical buildings and parks.

Measures:

- Additional protective measures (emergency plans) for libraries, museums and archives
- Impact monitoring and conservation measures on historic infrastructure

Rural areas, forest, agriculture and soil

In Saxony-Anhalt, 80% of the population lives in rural areas and 60% of the area is used for agriculture. Beyond agriculture and forestry production, the rural landscape is home to many ecosystem services, such as biodiversity preservation and recreational services. Climate change has the potential to degrade these industries.

A major pillar of adaptation in rural/agricultural areas is information, information services and capacity building. The latter is especially important in the form of vocational training for farmers. Monitoring the change of production factors is also important. This can either be done through 'permanent observation fields' and other long-term observations or by using measurement technology (lysimeters, soil analysis, etc.) to detect the effective change.

The major impacts in rural Saxony-Anhalt are soil erosion through wind and water and dry spells. The exposure is high and about 30% of the agricultural area is prone to erosion (water or wind). This rate is likely to increase under the expected effects of climate change. Consequently, erosion protection is addressed as follows: revision of the spatial planning base relevant for land conservation, in order to address the issue, resulting in hedges as wind breakers (and biodiversity zones) between fields.

The climatic water balance is already negative. It will likely become more negative, which means that water competition will become an issue, especially in the lee side of the Harz mountains. Monitoring surface- and groundwater is key. All water-related measures are inevitably linked to the EU Water Framework Directive and the EU Flood Directive. Both are very effective pan-European regulations to ensure sustainable water use and assess flood risk.

A good example of agricultural research on the climate impacts on crop production is the plant cultivation hall at the Leibniz Institute of Plant Genetics and Crop Plant Research (IPK) in Gatersleben. The IPK is one of the world's leading international institutions in the field of plant genetics and crop science. Their new plant cultivation hall is a cutting-edge laboratory for phenotyping plant lines and species. During the plant growth, the plants are monitored with a non-invasive automatic 3D-scanner, multispectral image technology and multiple sensors from above and within the soil. With such a system, it is possible to analyse the plant phenology and the relationship between genome and plant traits under different climate conditions. This 'plant cultivation hall' allows for detailed phenotyping under almost 'natural' conditions. It is possible to test crops under a future climate scenario over a whole growing period. This allows for more precise projections on plant yields in a changing climate.

Figure 2: Plant cultivation hall at IPK Gatersleben (c) G. Rappold

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Schleswig-Holstein

State and climate information

Population	2,900,000
Population density	180 Citizens/km²
Area	15,763.18 km²
GRP	62.7 billion EUR/year
GRP/cap.	21,600 EUR/year
99% of the enterprises are SME	

Schleswig-Holstein is the northernmost federal state in Germany. It borders Denmark to the north and the federal German states of Hamburg, Lower Saxony and Mecklenburg-Vorpommern to the south. The North Sea forms the border to the west (644 km) and the Baltic Sea to the east (686 km).[1] Schleswig-Holstein's exposure to the sea determines the prevailing climate impacts. The state is marked by lowlands and virtually no hills. The North Frisian Islands, as well as almost all of Schleswig-Holstein's North Sea coast are under conservation.

The main economic branches are renewable energy, health economy, maritime economy and tourism.[2] Schleswig-Holstein is a leader in the country's growing renewable energy industry. Since 2014, the state covers 100% of its electric power demand with renewable energy sources (primarily wind, solar, and biomass). Due to its rich nature and numerous islands, Schleswig-Holstein attracts millions of tourists every year. The tourism intensity is the second largest in Germany.[1]

Expected climate change

Between 2021 and 2050, the mean temperature is expected to increase between 1.0 and 1.3°C. Annual rainfall is not expected to increase substantially in the short term (2021-2050). However, in the long term, an increase of 10% is anticipated. The number of rainy days is also expected to increase.

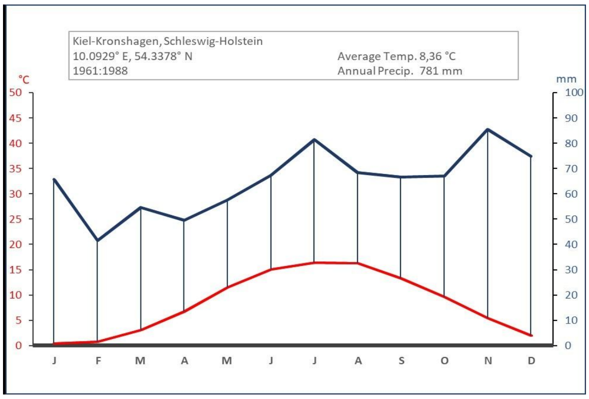

Figure 1: Climate characteristics in Kiel: Warm summers, no dry season. Temperature increase since 1881: 0.7°C (Own figure based on data from DWD)

Direct climate impacts

The rise of sea levels is a major issue of concern in Schleswig-Holstein. Without encompassing climate protection measures, the sea levels are predicted to rise up to one meter in the next 80 years (0.61 m. to 1.10 m.)[3]. Regional climate models predict a temperature increase of 3 to 5 °C by 2100. The growing season will be extended by 30 to 90 days. While storms occurred more often in the past years, there is little evidence that the likeliness of storms is generally on the rise. The expected major climate stresses include the following:

- Sea level rise
- Heat waves
- Dry spells
- Storms
- Heavy rain
- Floods (sea and inland)

[1] Statistisches Jahrbuch Schleswig-Hostein 2017/2018
[2] Industrie- und Handelskammer Schleswig-Holstein. (2012). Strategiepapier der IHK Schleswig-Holstein 2030. IHK Schleswig-Holstein.
[3] Landesregierung Schleswig-Holstein. (2019). Sonderbericht des Weltklimarats: Meeresspiegel könnte noch stärker steigen als bislang angenommen.

Action fields for adaptation measures to cope with climate change

To address the current and future challenges of climate change, Schleswig-Holstein's Ministry for Energy Transition, Agriculture, Environment, Nature and Digitalisation (MELUND) designed the roadmap for climate change adaption in 2018.[4] It is based on the German Adaptation Strategy (DAS) and adapted to the needs of the state.

The roadmap analyses short- and long-term climate change impacts and develops ways forward to mitigate risks. The roadmap includes indicators on measuring climate change and its impact on the abovementioned fields. It presents existing projects as well as recommendations for future interventions and includes projects on the municipal level.[4]

Water

The action field for water in Schleswig-Holstein covers water supply and wastewater, groundwater, marine ecology, coastal protection and inland flood protection. The distinct characteristics of the state are marine ecology and coastal protection.

Water: marine ecology

Sea-level rise and temperature increase impact the marine ecosystem. Under the most likely scenario of 25 cm. by 2050, no major changes for the ecosystem of the protected tideland in the North Sea are expected. However, under the worst case scenario of a 50 cm. increase by 2050, the tideland could change into a coastal lagoon area with more permanent water cover. The natural material relocation will not cope with the water increase given a lack of the necessary sediments.

In the Baltic Sea, an increase of 0.5°C to 2.5°C by 2100 is expected. Together with a decrease of the salt content, this could lead to a major reduction of sea ice in winter. Furthermore, the season for cyanobacteria will be extended. In the winter, sudden eutrophication peaks caused by river discharge may occur. Oxygen deficiency in the deep waters of the central Baltic Sea might be less severe.

Figure 2: Climate change affects the Schleswig-Holstein coastline. Areas marked in blue might be susceptible to rising sea levels

Measures

Research on the prevention of eutrophication, research and the close monitoring of the marine ecosystem, as well as sediment management for the tideland is ongoing.

Water: coastline

The predictions of the sea level rise, plus an expected wind set-up of up to 0.4 m., will result in an increase of water by more than one meter. For some sections of the over 1000 km. coastline, a retreat will be unavoidable. Wherever it is possible, dikes should be enhanced.

Measures include:

To increase dikes, a stepwise approach was chosen. This reduces investment costs and gains time. It also reduces the risk of the improper allocation of funds. Since the specific sea-level increase is unknown, the next enhancement stage will only be taken when needed. The actual planning contains a 'climate supplement' of 50 cm., but an additional reserve-space is kept for further enlargements.

This measure has high indirect costs. The additional needed space, for example, will in this case not be utilised for other purposes. This is important given that sea-side holiday apartments, shops and restaurants are a desirable asset for an economy that depends heavily on tourism.

[4] Umweltbundesamt. (2018). *Anpassung an den Klimawandel: Bundesland Schleswig-Holstein*.

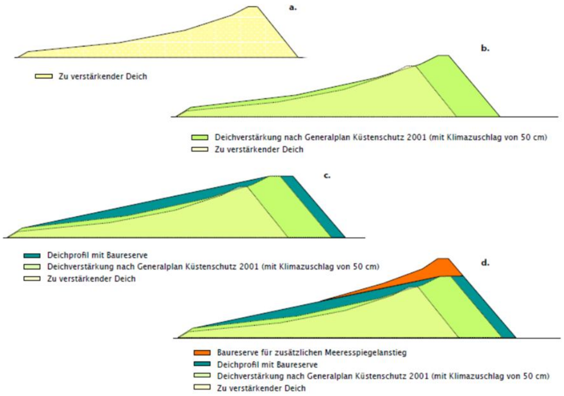

Figure 3: Measures to increase dikes in Schleswig-Holstein

Tourism

Tourism is a major economic sector in Schleswig-Holstein. It is closely linked to environmental protection and sustainability. Tourism is primarily present along the coast and is therefore particularly susceptible to the impacts of climate change. As mentioned above, current economic interests and strategy are often stuck in a conflict of interest.

Climate change can have both positive and negative effects, since rising temperatures may lead to longer tourist seasons. At the same time, the changing quality of water and increasing number of insects could lead to a higher likeliness of diseases. The necessary measures include promoting indoor activities, strengthening environmental protection in nature reservoirs and further developing concepts for sustainable tourism. In order to prevent target conflicts with other action areas, good regional coordination, especially regarding the distribution of public funds, is highly necessary.

A particular focus in the strategy is on developing opportunities on the municipal level. With regards to programmes on the local level, the government of Schleswig-Holstein provides opportunities and financial support for networking and knowledge development, as well as for pioneering projects such as Rain Ahead – an early warning system for heavy rain that contributes to the prevention of floods.[4]

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RESIN Climate Risk Typology

RESIN: Supporting decision-making for resilient cities

- The RESIN project investigated climate change adaptation practices in European cities to assess their impact and vulnerability. Its aim was to establish standardised methodologies and decision-making tools that cities and regions can use to develop local adaptation strategies.
- An interdisciplinary, pan-European group of research institutes and universities worked in cooperation to execute the project.
- The European Union (EU) Horizon 2020 Research and Innovation Programme funded the project. With nearly €80 billion in funding (2014-2020), Horizon 2020, which aims to secure Europe's global competitiveness in science and industry,[1] is the EU's largest research and innovation programme.

RESIN responds to a lack of standardisation

The European Climate Adaptation Strategy (2013-2016) highlights the need for strategies and actions that focus on climate risks in response to Europe's rapidly changing climate conditions. RESIN responds to the problem of excessive variation in the approaches and methods used by European cities to develop a climate adaptation strategy. This limits their ability to compare vulnerabilities, adaptation options, infrastructure and resilience capabilities. Not only does the lack of standardised information limit constructive exchange between cities – it also makes it more difficult to develop European responses to climate change.

RESIN project aim

RESIN's aim is to create a unifying framework for climate change adaptation to facilitate the comparison of strategies/results and identify best practices. First, the project developed standardised adaptation tools and approaches. These help cities share knowledge and capabilities, as well as support one another in developing their resilience capacity. Second, the project's research partners are currently developing an urban typology to characterise European cities according to a number of features (including morphology, size, economic and infrastructural texture, etc.) to facilitate knowledge sharing and exchange.

The Climate Risk Typology

As one of the RESIN project's deliverables, the climate risk typology responds to a lack of standardisation on climate risks on a European level. Climate risks vary spatially across Europe's cities and regions, as do approaches to visualise and analyse theses spatial patterns. **This is a barrier to strategic adaptation planning and resource allocation.**

Approach of the typology

The Climate Risk Typology is based on the PICC AR5 risk framework. It defines risk as a function of climate hazard, exposure and vulnerability (which encompasses sensitivity and adaptive capacity). The scale of the typology is the European NUTS3 (small regions for specific diagnoses), derived from official EU statistics. The population in a NUTS3 region range from 150,000 to 800,000 inhabitants, corresponding to the districts (*Landkreise*) in Germany.

[1] https://ec.europa.eu/programmes/horizon2020/sites/horizon2020/files/281113_Horizon%202020%20standard%20presentation.pdf

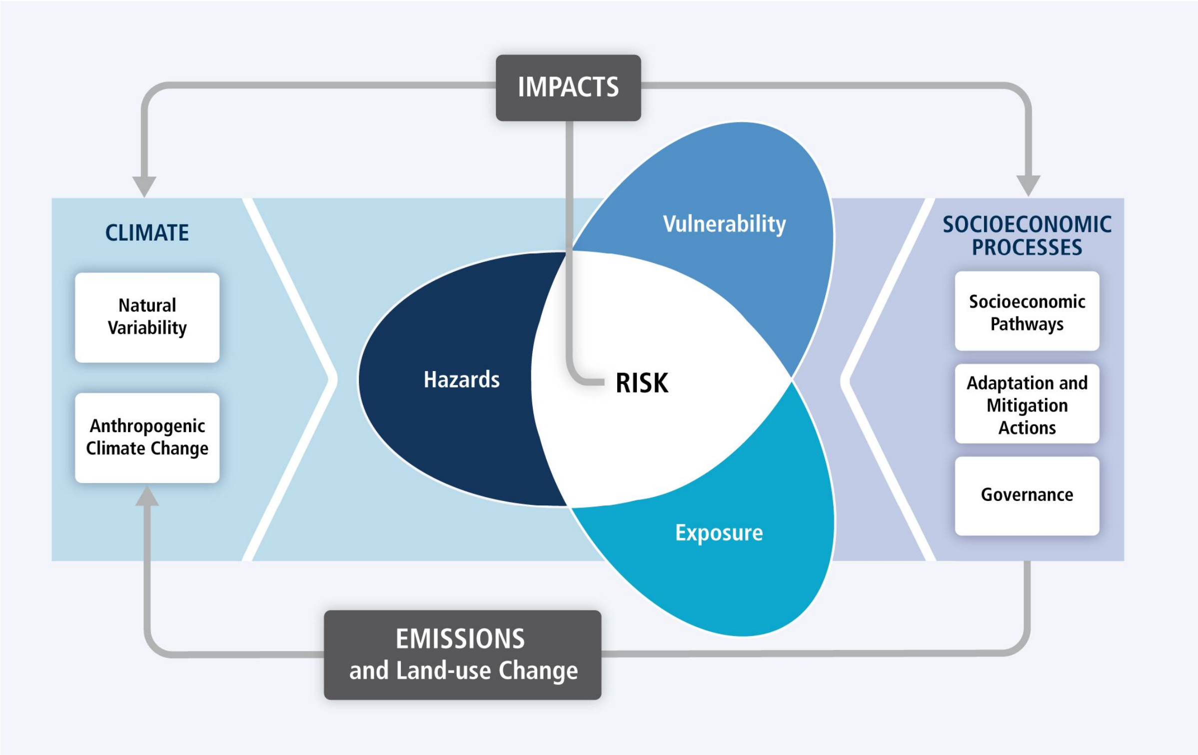

Figure 1: Risk IPCC AR5

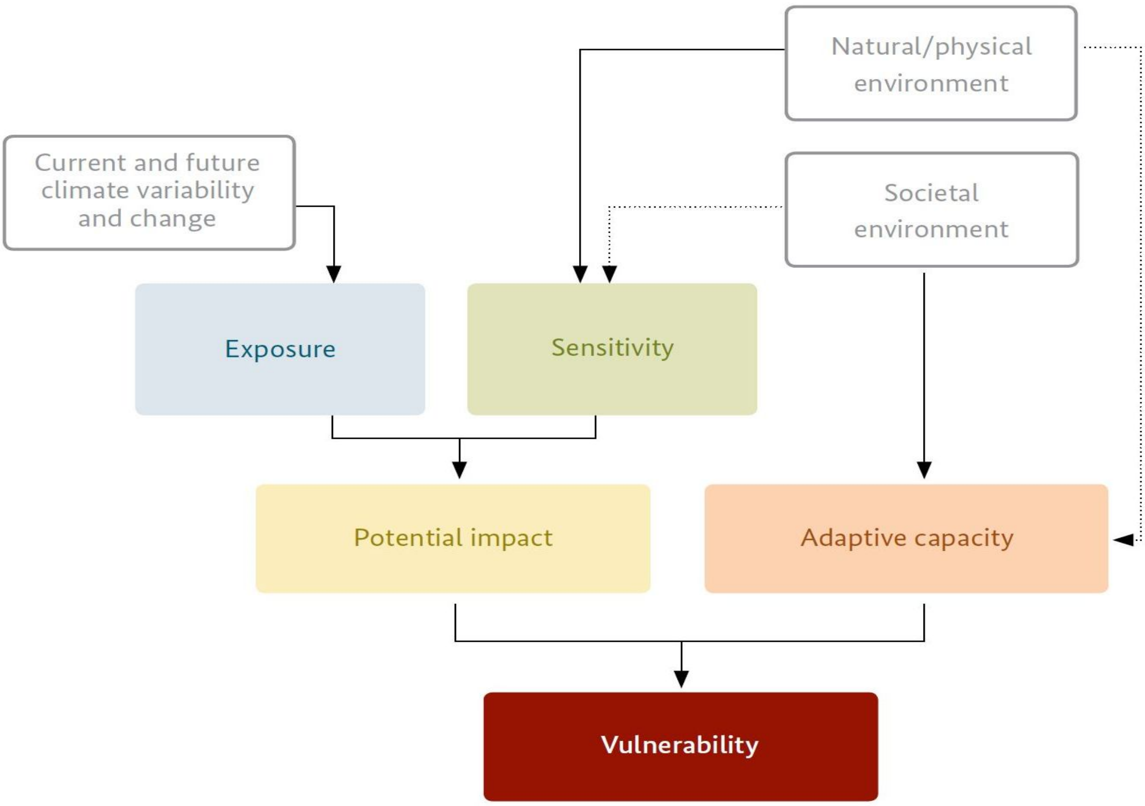

Figure 2: Fritzsche et al. (2014)

Indicator Selection

- **Hazards:** A hazard is a 'potential occurrence of a natural or human-induced physical event that may cause loss of life, injury or other health impact, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources' (final report, p. 22). Hazards are related to extreme weather and climate change and require adaptation and resilience building in response. The hazard indicators in the typology include: Wildlife hazard, coastal hazard, drought hazard, fluvial (flood) hazard and landslide hazard.

- **Exposure:** Exposure is defined as 'the presence of people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social or cultural assets in places that could be adversely affected' (IPCC 2014a: 123). Exposure can thus be understood as the extent to which receptors (including people, infrastructure, assets) are located in areas that could be affected by hazards. It is a spatially-oriented concept.

- **Vulnerability:** Vulnerability is comprised of sensitivity and adaptive capacity. *Sensitivity* to climate change is driven by personal characteristics of the population, characteristics of physical or economic assets and issues which affect the broad functioning of the city system (Swart et. Al, 2012). For example, it is generally recognized that older and younger people are more affected during heatwaves and floods. Age indicators can thus provide useful insight into the broad trends in these areas. Economic assets or lack thereof can also enhance sensitivity.

- **Adaptive Capacity:** Adaptive capacity on the NUTS 3 level is divided into: awareness of the problem, the ability to adapt and the capacity to take adaptive action.

Typology Outputs

The European Climate Risk Typology is housed in an interactive online portal that can be accessed on: *http://european-crt.org/index.html*. The generated outputs consist of the following:

- Interactive maps showing climate risk classes and sub-classes (groups of European cities and regions sharing similar risk characteristics)
- Information on climate risk indicators
- Information on its application and uses

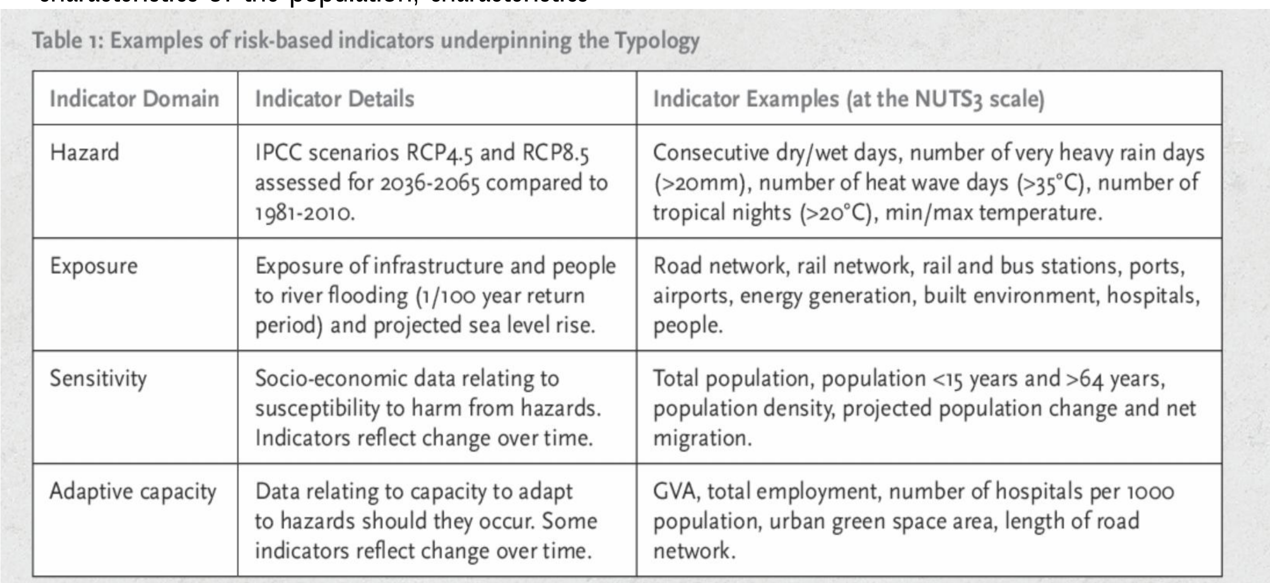
Table 1: Examples of risk-based indicators underpinning the Typology

Indicator Domain	Indicator Details	Indicator Examples (at the NUTS3 scale)
Hazard	IPCC scenarios RCP4.5 and RCP8.5 assessed for 2036-2065 compared to 1981-2010.	Consecutive dry/wet days, number of very heavy rain days (>20mm), number of heat wave days (>35°C), number of tropical nights (>20°C), min/max temperature.
Exposure	Exposure of infrastructure and people to river flooding (1/100 year return period) and projected sea level rise.	Road network, rail network, rail and bus stations, ports, airports, energy generation, built environment, hospitals, people.
Sensitivity	Socio-economic data relating to susceptibility to harm from hazards. Indicators reflect change over time.	Total population, population <15 years and >64 years, population density, projected population change and net migration.
Adaptive capacity	Data relating to capacity to adapt to hazards should they occur. Some indicators reflect change over time.	GVA, total employment, number of hospitals per 1000 population, urban green space area, length of road network.

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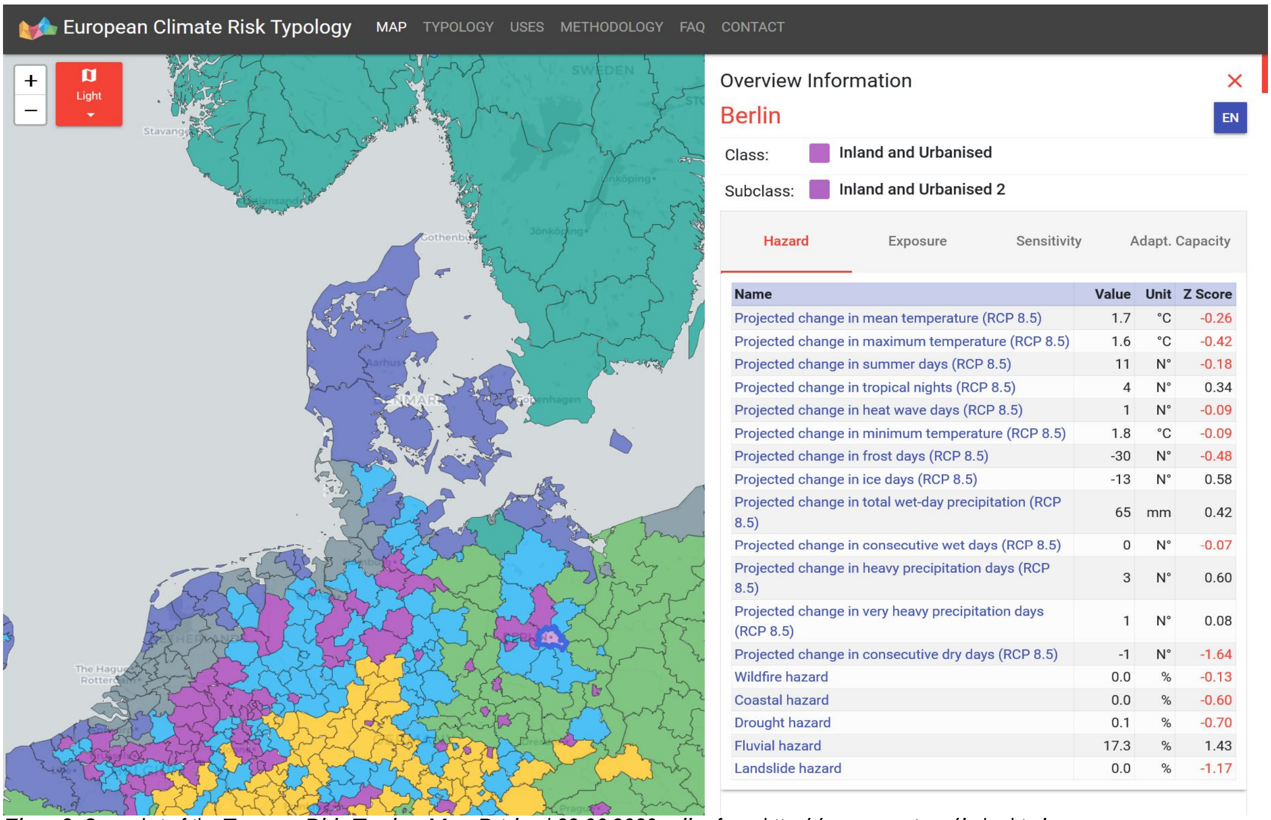

Figure 3: Screenshot of the European Risk Typology Map. Retrieved 22.06.2020 online from: http://european-crt.org/index.html

Potential users

The typology seeks to support policymakers, practitioners and researchers in better understanding and responding to climate change risks. The process of development and testing of the typology included input from potential end users (both from within and outside of RESIN) and identified multiple key uses and users of the typology.

Benefits of an online typology on climate risks

- **Risk Assessment:** In combination with additional data, the indicators can be used to conduct a spatial risk assessment.

- **Awareness raising:** The typology provides an easy-to-use, comprehensive online portal. The supporting indicators help to visualize, communicate and raise awareness on climate risk amongst different stakeholder groups. Users may use the typology in the early stages of an adaptation planning process to generate commitment for adaptation and resilience action.

- **Network development:** Standardised regional data foster exchange between cities and regions that share similar risks from climate change. Users can use the typology to help develop networks between regions in order to share knowledge, experience and practice.

- **Baseline:** A typology provides a snapshot of the risk indicators during the time of its development. Through the constant updating of indicators, it provides a baseline for monitoring climate change over time.

- **Description:** A climate risk typology provides an overview of a climate risk landscape. It can thus be used to enhance understanding of climate risk characteristics.

- **Strategy and plan development:** A typology can help guide decision-making on climate risks and assist the user in allocating resources to particular areas of need or opportunity.

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The Adaptation Options Library (AOL)

Well-structured operational and standardised tools for identifying and implementing highly-efficient and effective adaptation options are scarce. This results in a knowledge gap on the increased understanding of the applicability and cost effectiveness of adaptation options.

The Adaptation Options Library (AOL) is a comprehensive database of adaptation options related to heat, pluvial, fluvial and costal floods, droughts and windstorms. The library draws from over 300 papers and 700 scenario cases. This allows municipal experts, developers and consultants to elaborate a preliminary portfolio of feasible adaptation measures for their respective areas.

AOL synthesises scientific literature and information on cost efficiency, heat and flood effectiveness, vulnerability reduction effectiveness (sensitivity reduction, adaptive capacity increase) and option implementation.

AOL also attempts to harmonise the metrics for effectiveness evaluation and to determine a range of effectiveness and cost efficiency for each option. It enables users to rank adaptation options according to their effectiveness and cost efficiency, aiding decision-makers in identifying a portfolio of adaptation options to consider, select and combine. AOL thus serves as a reference for practitioners to compare the options available for tackling climatic

[1] https://ec.europa.eu/programmes/horizon2020/sites/horizon2020/files/281113_Horizon%202020%20standard%20presentation.pdf

hazards (principally heat and flooding) and to identify the most suitable options.

AOL approach

To develop the database, the AOL team identified the main criteria for the characterization and evaluation of climate adaptation options. These criteria were then used for the prioritization processes (task 3.2, D3.2). Information on the various options was collected from existing adaptation option databases, platforms and libraries, scientific reports and climate adaptation policy documents. The review process considered ongoing and completed projects, research and initiatives (published reports and papers) and existing climate platforms and websites. All source references are included in the database.

AOL is based on a relational model that includes all key analytical dimensions (criteria) considered for a complete characterisation of the adaptation options assessed in RESIN. The database is designed and implemented with open-source standard tools and protocols for database management (MySQL).

The database is organized into four domains: general information, effectiveness (including head, flood and vulnerability reduction), cost efficiency and implementation. Each domain consists of several dimensions and sub-dimensions. This is further explained in the D3.1 "Library structure online. Adaptation options database model[14]".

The RESIN partner cities along with a 2^{nd} tier of neighbouring cities provided feedback during the design and implementation of AOL, which was integral in ensuring the utility of the final product.

The cities answered a questionnaire on the required functions of the database, the result of which were integrated into the second version of the library. The aim of this step was to make AOL more user-friendly and better adapted to the partners' needs.

The Adaptation Options Library (AOL) includes:

- A large collection of literature references on adaptation options that have been modelled or already implemented at the city level across Europe and worldwide;
- Standardisation or harmonisation for characterising the adaptation options in terms of costs and benefits linked to specific conditions of implementation;
- An accessible library of adaptation options that allows benchmarking and classifying in a number of relevant dimensions.

Outputs

AOL covers an extensive array of adaptation measures related to heat, pluvial, fluvial and coastal floods and drought. The presented measures include general information as well as information regarding their effectiveness, cost efficiency and co-benefits (examples in the figures below).

The adaptation measures can be filtered and searched. This helps the user rank measures in order to achieve a defined objective (e.g. reduce the air temperature by 1°C).

The list of adaptation measures is nonetheless non-exhaustive, with not all hazards covered. Furthermore, effectiveness and cost efficiency data are not available for all options.

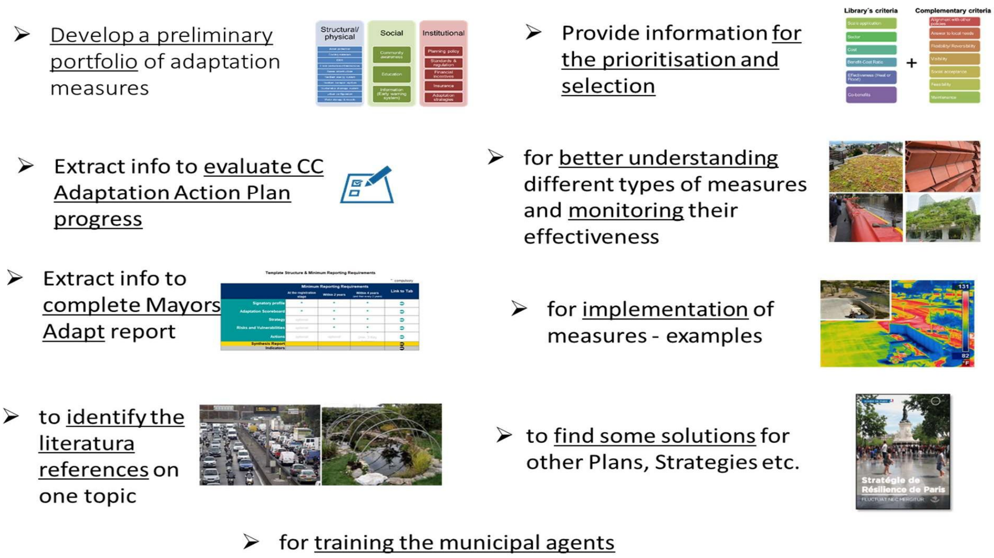

Figure 1: Potential uses of the Adaptation Options Library (AOL)

Intended use

The website can be used in 'quick view' and 'general view' mode. In quick view mode, the database screen is divided into two screens: a) an information screen where the selected data is shown and b) different tabs to select or organize the desired type of information (see Figure 4).

On the information screen, the user can view the different adaptation options, including name, picture, definition and performance, intuitively.

- PERFORMANCE INFORMATION: If available, a qualitative assessment (very good, good, bad) of the option's cost efficiency and heat/flood effectiveness. This assessment is based on the reported literature (details in Methodology, 2.3 section).

Furthermore, there are three functions to filter or search specific information:

- FILTERS: Filters the information by hazard type, scale of the option's implementation, climatic region where the option was implemented or studied, type of option by the IPCC's classification of adaptation options, group of options, target of the option and sector to which the option is applicable.
- KEYWORDS SEARCH FUNCTION: Identifies studies that contain one or more words specified by the user.
- FAVOURITES SELECTION: Marks the measures or groups of measures (by clicking on the star) as favourites. The user can choose to display only these favourites and create their own collection of options.

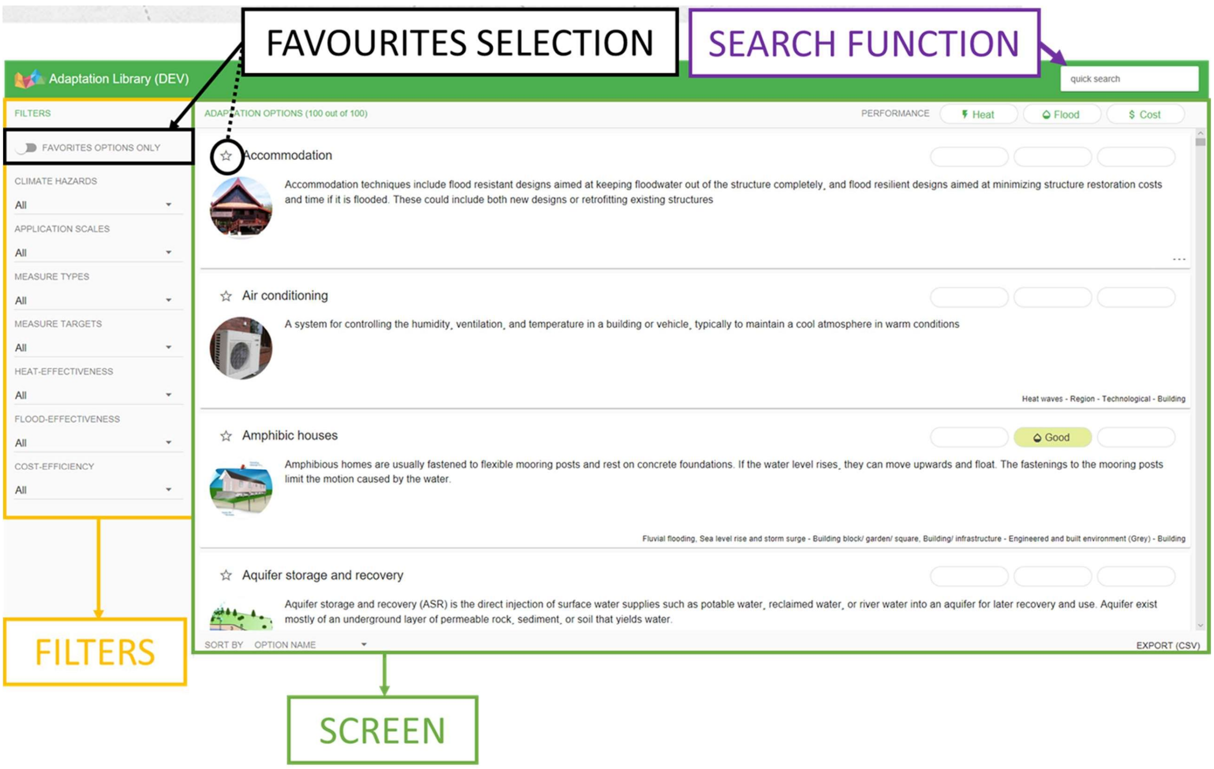

Figure 2: The screen of the quick AOL with all available features

The 'quick view' option also offers additional details when clicking on the specific measure (Figure 3):

- Description of the adaptation option
- Co-benefits (potential) of the adaptation option
- Negative effects (potential) of the option
- Standards, if available
- Group of adaptation options it belongs to
- Climatic hazard it tackles
- Different scales at which the adaptation option can be implemented
- Type of measure, based on the IPCC's classification
- Minimum, average and maximum values for a certain heat effectiveness, flood effectiveness or cost-efficiency variable

From this window, the user can access the complete database (general view) by clicking on the button in the top-right corner. Furthermore, the user can print the information in this window or mark the adaptation option as a favourite. This allows practitioners to build a portfolio with the relevant options for their city or project. From this window, the user is able to access the complete database via the 'general view' mode.

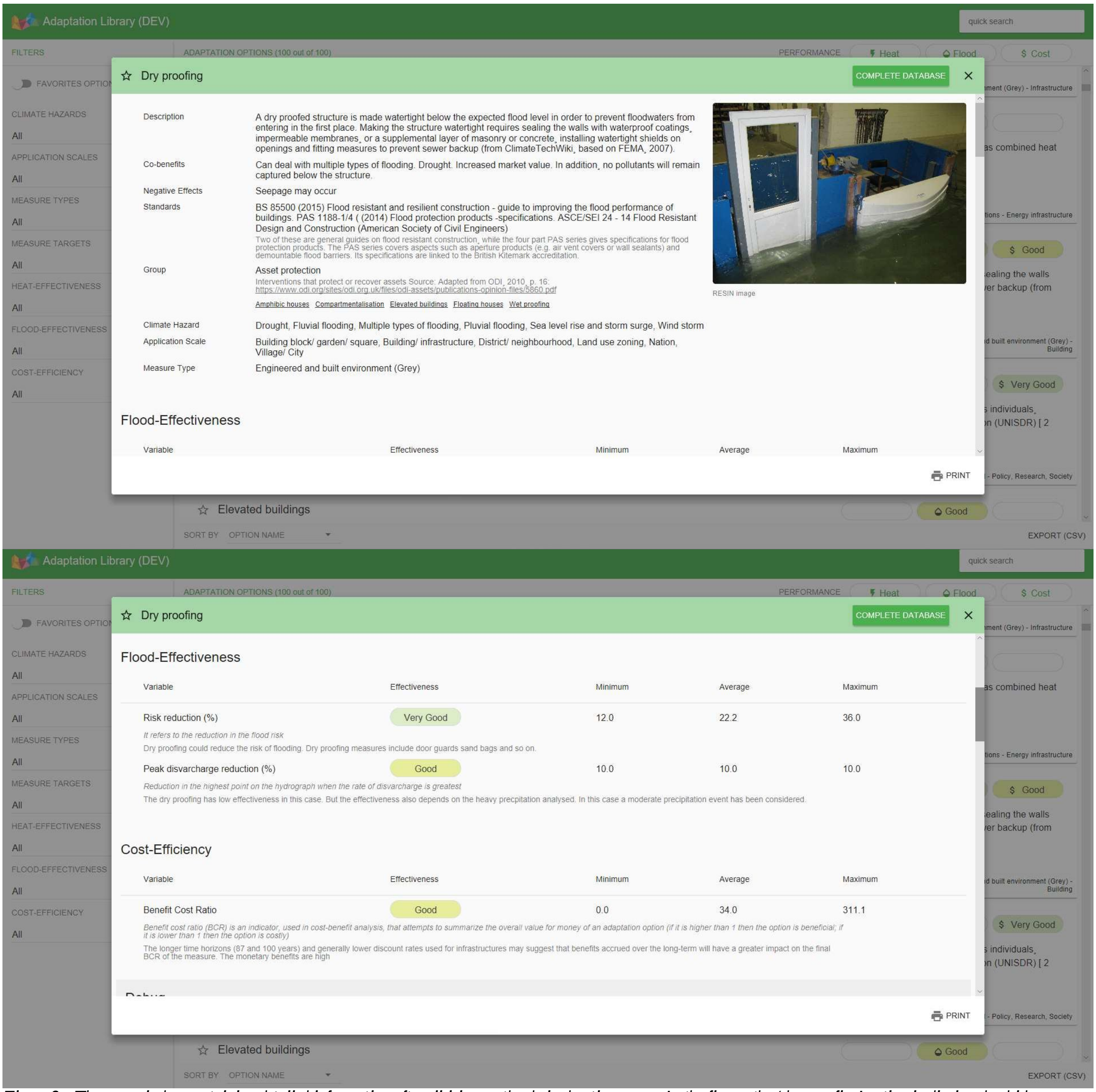

Figure 3: The new window containing detailed information after clicking on the desired option name. In the figure, the 'dry proofing' option is displayed, which reduces flood risk by an average of 22% and peak discharge by an average of 10%

In the ‘general view’ mode, there are two levels of information to choose from:

- ‘Options’ – provides an overview of the chosen option, including existing literature;
- ‘Study cases’ – provides information related to the research performed

Information provided for each measure includes:

- **General**: Basic information (co-benefits, hazard, type, climatic region, etc.)
- **Costs**: Cost-benefit ratio of the measure
- **Heat**: Indicates how much air temperature is reduced due to an adaptation measure
- **Flood**: Indicates how much flood hazard is reduced due to an adaptation measure
- **Vulnerability**: Provides quantitative information regarding the effectiveness of an option on reducing vulnerability
- **Implementation**: Provides information related to the parties involved (responsible stakeholders, external stakeholders, beneficiaries, target stakeholders) and the ease of an option (feasibility, barriers, maintenance)

Known use cases

AOL was created in cooperation with the cities of Bilbao, Paris, Bratislava and Greater Manchester. Bratislava made use of the assessment of adaptation measures in the AOL while summarising the information required by the Mayors Adapt monitoring framework, to which Bratislava is signatory. Bilbao used AOL to extract options for its adaptation plan.

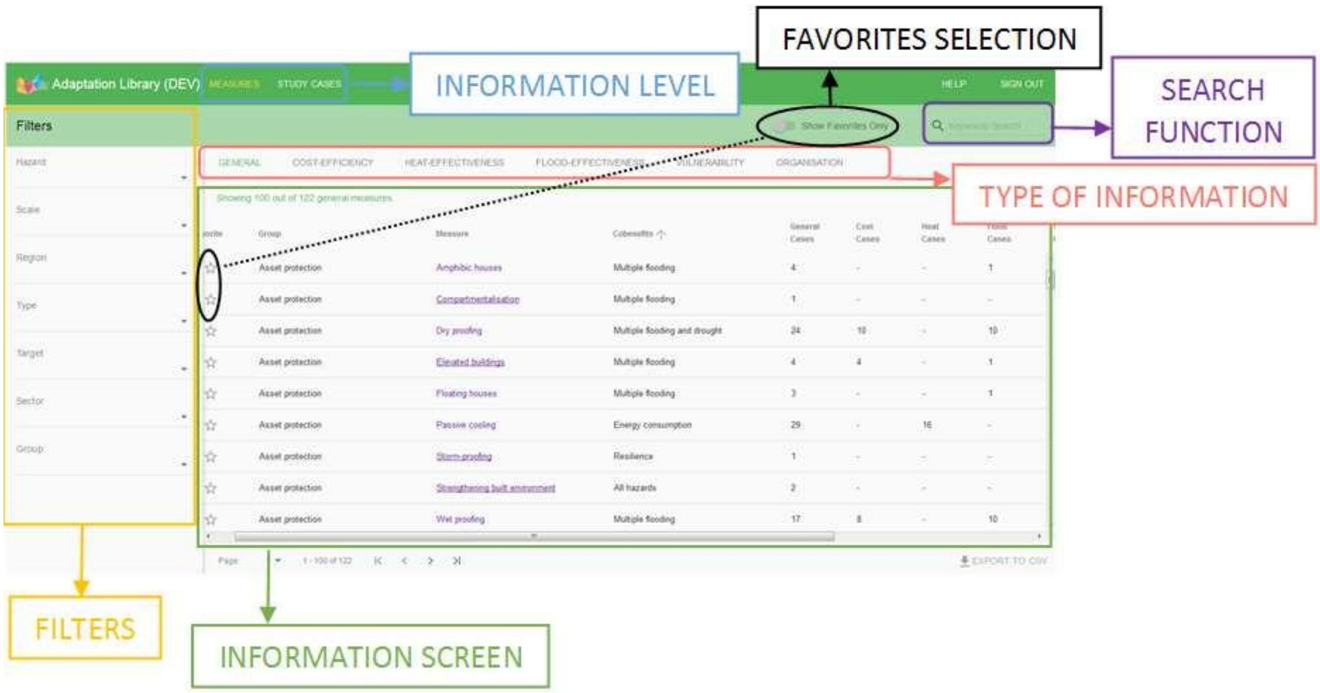

Figure 4: The screen of the general AOL with all available features

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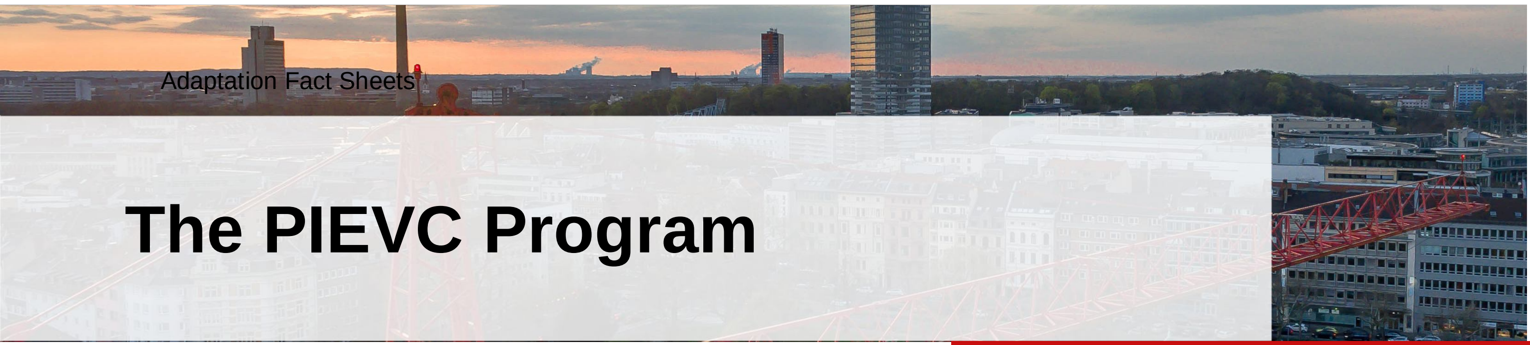

The PIEVC Program

Protocol for infrastructure climate risk and vulnerability assessment

The PIEVC Protocol

The "PIEVC Engineering Protocol for Infrastructure Vulnerability Assessment and Adaptation to Climate Change" (PIEVC Protocol) was developed by the "Public Infrastructure Engineering Vulnerability Committee" of Engineers Canada. In March 2020, they transferred the intellectual property rights to the Institute for Catastrophic Loss Reduction (ICLR), which will operate the PIEVC Program worldwide in cooperation with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).

The Protocol has been applied to a wide range of infrastructure types including buildings, storm water systems, roads, bridges, dams, water supply and waste water systems, electricity distribution and airport infrastructure.

Unlike other climate-related vulnerability assessments that address spatial, sectoral or socio-economic entities, this protocol only addresses infrastructure or infrastructure components, making assessment more precise. The object (infrastructure) and exposure (meteorological incidents) are more clearly defined. As an engineering exercise, PIEVC is result-oriented and pragmatic. It can handle data scarcity, tight timelines and limited budget resources – constraints that may affect the robustness of the assessment, but transparently document assumptions and identify limitations.

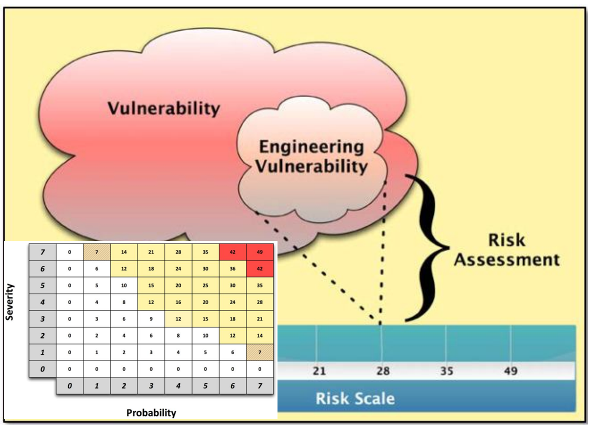

Figure 1: Engineering Vulnerability and Risk Matrix in the PIEVC Protocol (source: Engineers Canada & Lapp 2016)

A five-step process

The Protocol consists of a five-step process (see Figure 2). The first step collects data and information about the climate and infrastructure characteristics. The next step is to relate the respective information about climate, infrastructure and how they interrelate. Depending on how the interactions impact the infrastructure, it is classified as either vulnerable or adaptive to climate change. The engineering vulnerability – a specific subset of the overall vulnerability – is subsequently determined (see Figure 1).

Step 1 – Project definition

The first step entails gathering key information to generate a detailed description of the infrastructure of interest. This involves the identification of major documents and information sources. The relevant factors, including location, age, life cycle and historical climate set the boundary conditions for the vulnerability assessment.

Step 2 – Data gathering & sufficiency

The second step consists of two key activities: the specification of the features of the infrastructure being considered, and the identification of applicable climate information based on the description developed in Step 1. The first activity includes physical components, performance measures, technical data and operation/maintenance practices. The second activity is an interdisciplinary process that requires engineering, climatological, operational, maintenance and management expertise.

Step 3 – Risk assessment

Step 3 considers the relationship between infrastructure, climate and other factors. After identification of the interaction between the infrastructure's components – which are likely sensitive to the impact of climate change – a risk assessment of the infrastructure's vulnerability to changing climate is performed. The PIEVC uses a conventional 'engineering risk' approach and defines risk as the product of the *probability* of an unwanted incident and the *severity* of its consequences. The probability-severity relationship is described in the rise matrix and results in the risk scale (see Figure 1).

Step 4 – Engineering analysis

The engineering analysis is an optional step that builds on the previous step. The interaction between the infrastructure/its components and the climate, which requires further assessment, is identified through a vulnerability indicator analysis. The results allow for the determination of whether a vulnerability and adaptive capacity exists.

Step 5 – Recommendations and conclusion

The recommendations are a critical decision point at which the owner of the infrastructure must decide whether or not to conduct a further triple bottom line (TBL) analysis. If yes, additional resources and information is to be collected in order to build the adaptation scenarios. The TBL analysis addresses the economic, environmental and social aspects of the infrastructure vulnerability.

The next and final step for both options is reporting. The report should establish risk mitigation alternatives and recommendations that balance a range of technical, social, environmental and economic factors. It should address the following categories:

- Remedial action to upgrade the infrastructure;
- Management action to account for changes in the infrastructure capacity;
- Continuation of monitoring performance of infrastructure and its subsequent re-evaluation;
- No further action is required and/or;
- There are gaps in data availability or data quality that require further work.

Further information on robustness or required actions may be necessary. A statement about the overall infrastructure vulnerability is advisable.

Team of practitioners

The protocol is a pragmatic and straightforward approach to address infrastructure vulnerability and the team of practitioners is critical for its assessment. Professionals stem from climate science, engineering, operations, maintenance and management. The technical terminology and disciplinary peculiarities should be addressed explicitly to ensure clarity.

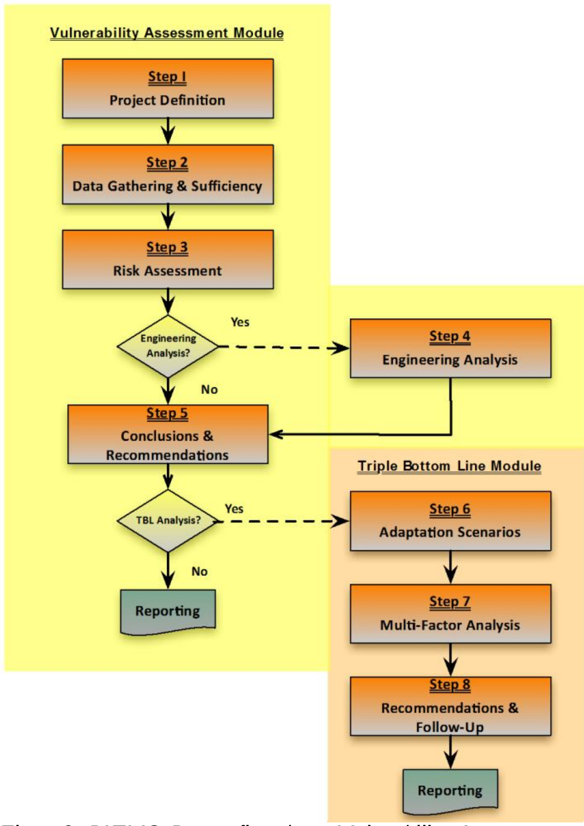

Figure 2: PIEVC Process flow chart. Vulnerability Assessment and Triple Bottom Line Module (source: Engineers Canada & Lapp D. 2016)

Reference

Engineers Canada, & Lapp, D. (2016). PIEVC Engineering Protocol (Issue June, pp. 1–76). Ottawa, Ontario: Engineers Canada. Retrieved from https://pievc.ca/protocol

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