MISSION CE CLIMATE TRAINING III:

Addressing Climate Challenges and Enhancing Adaptation Strategies

Feb 15th, 2024

Focus area: Precipitation-based climate risks

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Interreg CENTRAL EUROPE

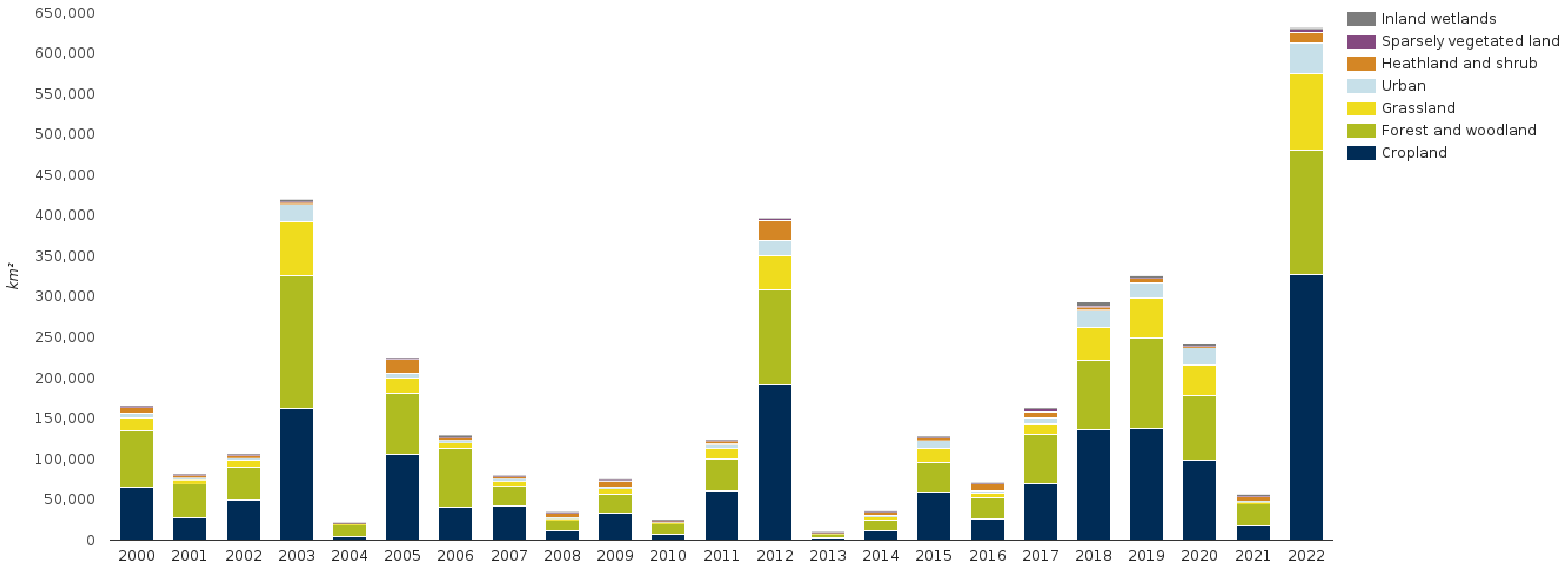
Co-funded by the European Union

MISSION CE CLIMATE

UNIVERSITY OF LJUBLJANA | BF Biotechnical Faculty

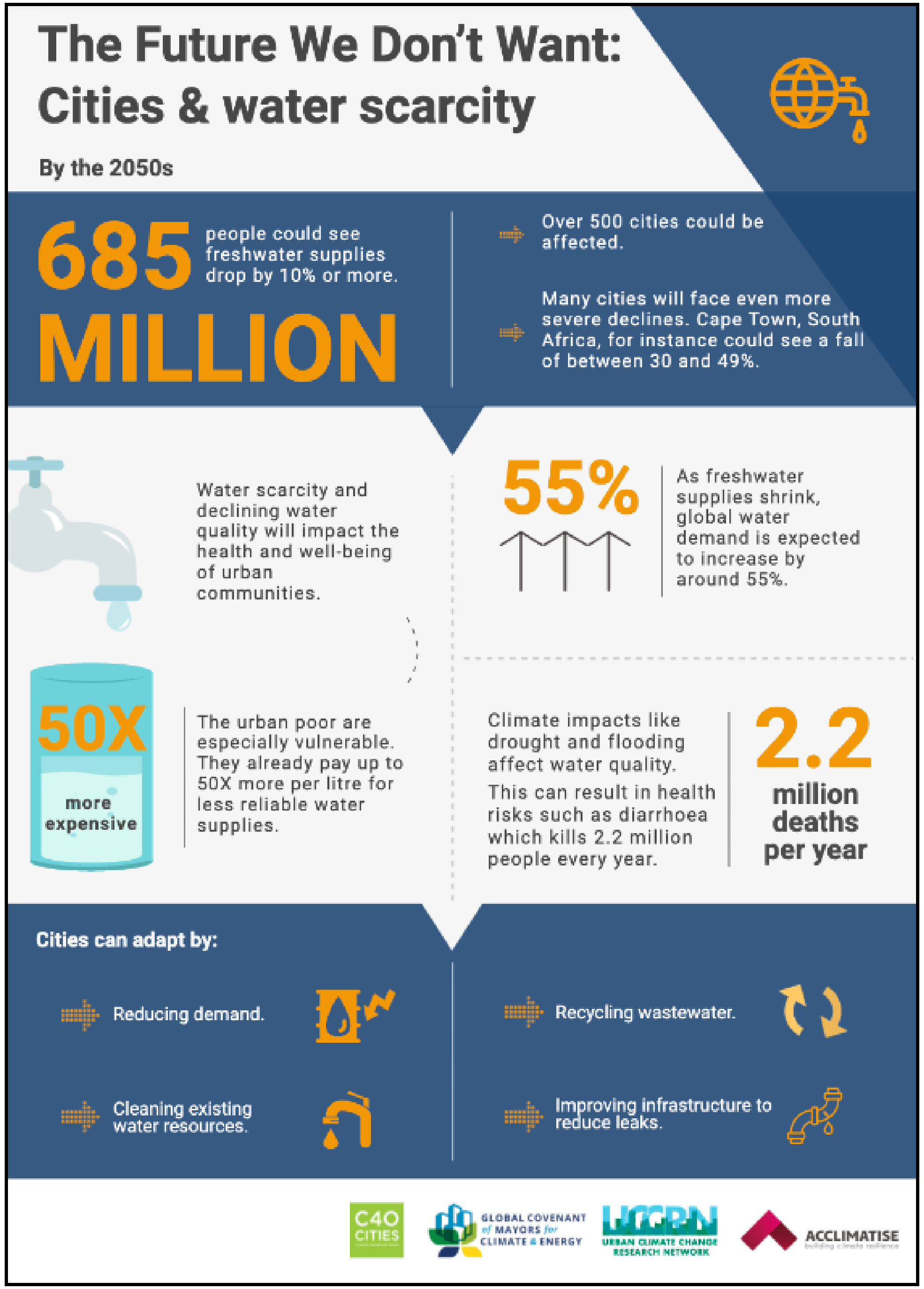
EEA (2023) https://www.eea.europa.eu/en/topics/in-depth/climate-change-impacts-risks-and-adaptation?activeAccordion=e53c3d45-3510-42da-bd18-cc72d0fb1a7b

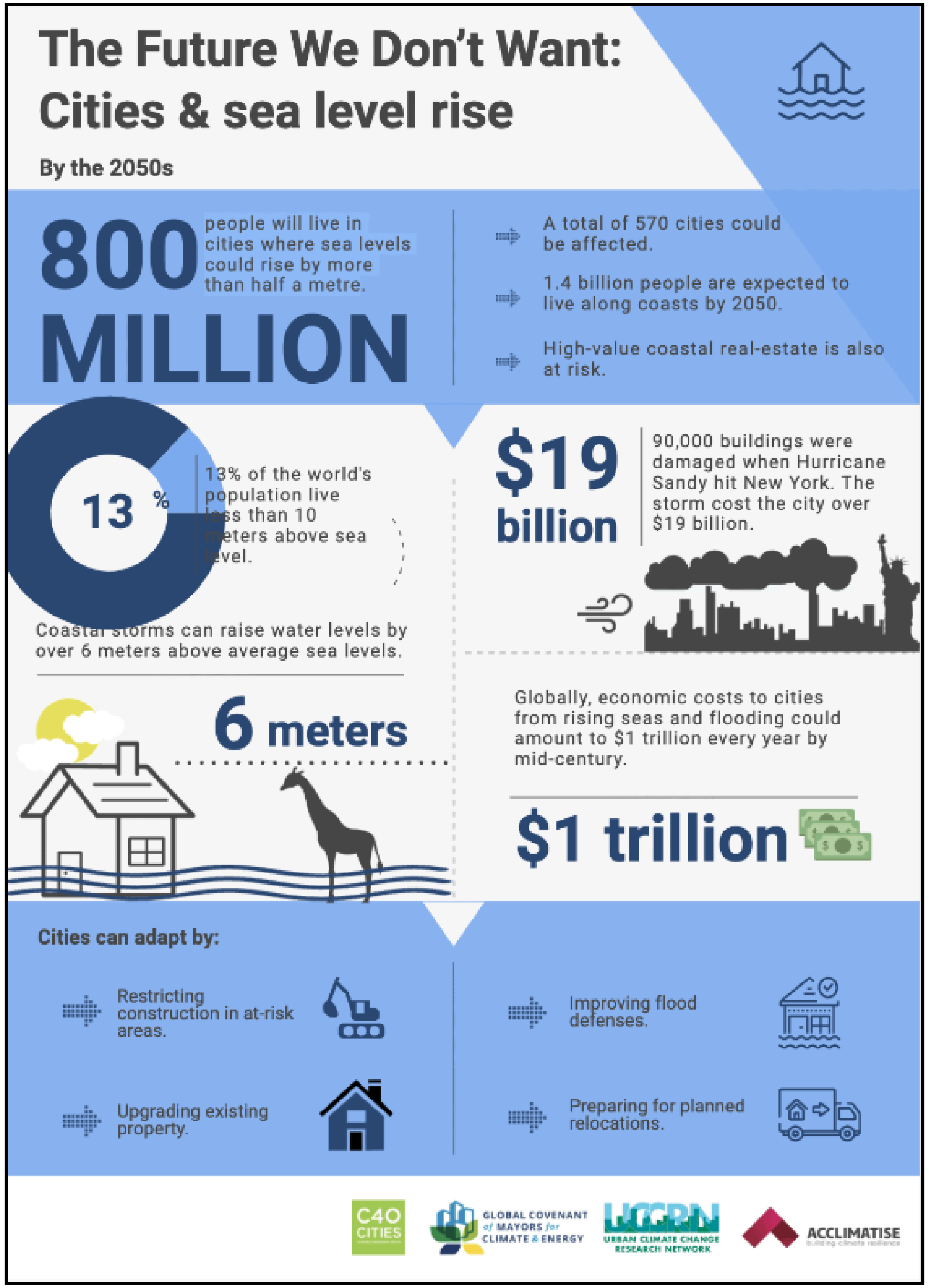
Chart — Annual area of drought impact on vegetation productivity for 2000-2022, EU-27 (km²)



Note: The figure shows the annual area of land affected by drought in the 27 EU Member States (EU-27) from 2000 to 2022, by ecosystem type. That is, it shows the area in km2 in which vegetation productivity was below the long-term average because of droughts in a 500m×500m grid cell each year.

EEA (2023) https://www.eea.europa.eu/en/analysis/indicators/drought-impact-on-ecosystems-in-europe





https://www.c40.org/what-we-do/scaling-up-climate-action/adaptation-water/the-future-we-dont-want/

Box 2.3 Examples of economic impacts of catastrophic events

Population: 5 530 754 (Dresden)
596 958 (Genoa)
302 835 (Malmö)
Biogeographic region:
Central and eastern Europe/
Mediterranean

The 2002 flooding in Dresden (Germany) caused about EUR 80 million worth of damage to community services alone. The damage to flood protection infrastructure cost an estimated EUR 300 million. Damage to agriculture and forestry is estimated at about EUR 45.6 million. Flooded public and private buildings suffered several more millions of euros' damage.

The 2014 flash flood in Genoa (Italy) caused damage to buildings and their contents of approximately EUR 100 million, according to estimates by the CIMA Foundation, and exposed 12 710 residents to risk.

In August 2014, a cloudburst in Malmö (Sweden) caused damage in excess of SEK 250 million (EUR 26 million) in immediate insurance claims and over SEK 100 million (EUR 10 million) in clean-up costs for the city. In insurance claims alone, that single flood accounted for approximately one third of the annual costs from flooding in the city. We still do not know the total costs. One year after the event, insurers had yet to process hundreds of claims.

Photo: © Landeshauptstadt Dresden, Umweltamt

Sources: http://statistik-dresden.de/archives/7823; http://statistik-dresden.de/archives/7794; Forcade, 2016; Mottaghi, 2015; http://www.sydsvenskan.se/malmo/ett-ar-efter-oversvamningarna-i-malmo.

EEA: Urban adaptation in Europe, 2020

Slovenian floods, August 2023
(https://www.24ur.com/novice/slovenija/pregled-najhujsih-poplav-v-sloveniji-najbolj-smrtonosne-so-bile-na-celjskem-leta-1954.html)

Historical precipitation trends and climate projections for Central Europe

Global Temperature

↑ 1.2 °C above pre-industrial level

More

European Temperature

↑ 2.2 °C above pre-industrial level

More

Arctic Temperature

↑ 3 °C above pre-industrial level

More

Carbon Dioxide (CO_2)

↑ 417 **ppm**, annual average level

More

Carbon Dioxide (CO_2) Increase

↑ 2.4 **ppm per year**, since 2010

More

Methane (CH_4)

↑ 1894 **ppb**, annual average level

More

Global Glaciers

↓ 8600 **km^3**, ice loss since 1997

More

European Glaciers

↓ 960 **km^3**, ice loss since 1997

More

Greenland Ice Sheet

↓ 5850 **km^3**, ice loss 1992-2020

More

Global Sea Level

↑ 9.7 **cm**, increase since 1993

More

Global Sea Surface Temperature

↑ 0.5 **°C**, increase since 1980

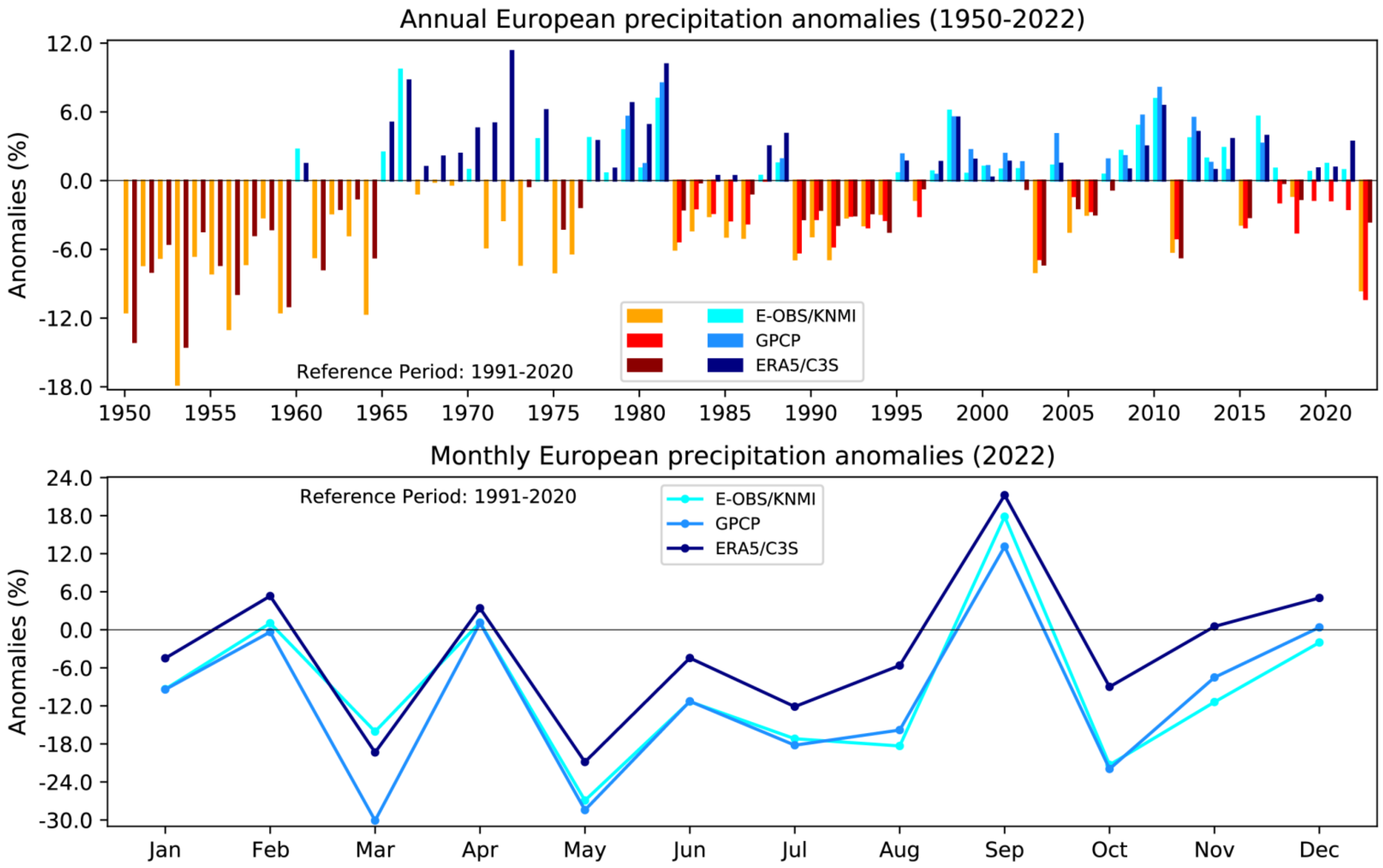
More

Arctic Sea Ice Extent

↓ 2.6 **million km^2**, September loss between 1980s and 2010s

More

Copernicus Climate Service, https://climate.copernicus.eu/climate-indicators

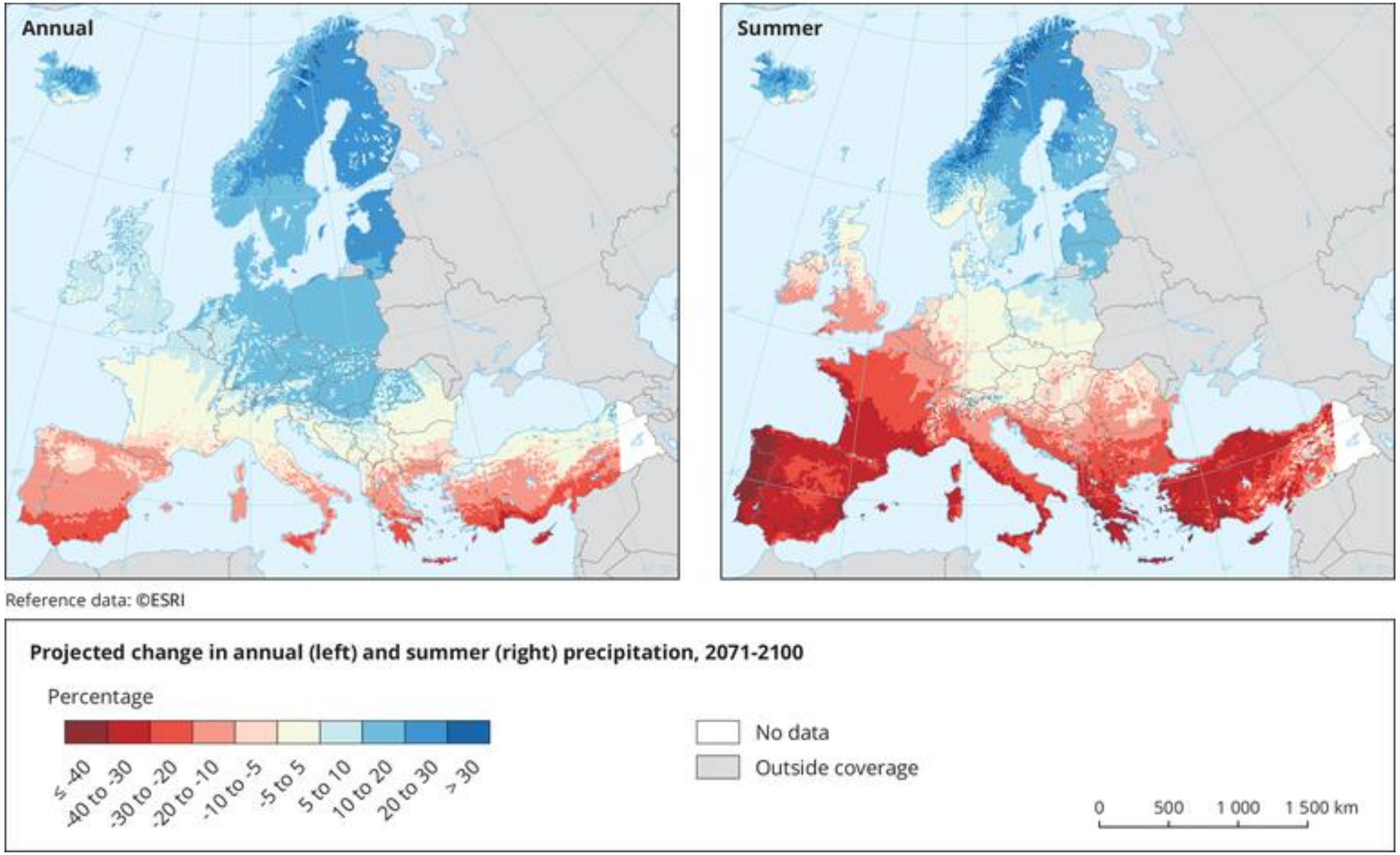


Copernicus Climate Service, https://climate.copernicus.eu/esotc/2022/precipitation

Copernicus Climate Change Service European State of the Climate | 2022 — PROGRAMME OF THE EUROPEAN UNION — Copernicus Europe's eyes on Earth — IMPLEMENTED BY ECMWF

Figure 1. (Top) Annual European precipitation anomalies (%) over land from 1950 to 2022. The anomalies are expressed as a percentage of the annual average for the 1991–2020 reference period. Data source: E-OBS[1] (light blue and orange, starting in 1950), GPCP (blue and red, starting in 1979), and ERA5 (dark blue and dark red, starting in 1950). (Bottom) Monthly European precipitation anomalies (%) over land in 2022. The anomalies are expressed as a percentage of the monthly average for the 1991–2020 reference period. Data source: E-OBS[1] (light blue), GPCP (blue), and ERA5 (dark blue). Credit: C3S/KNMI/DWD/ECMWF.

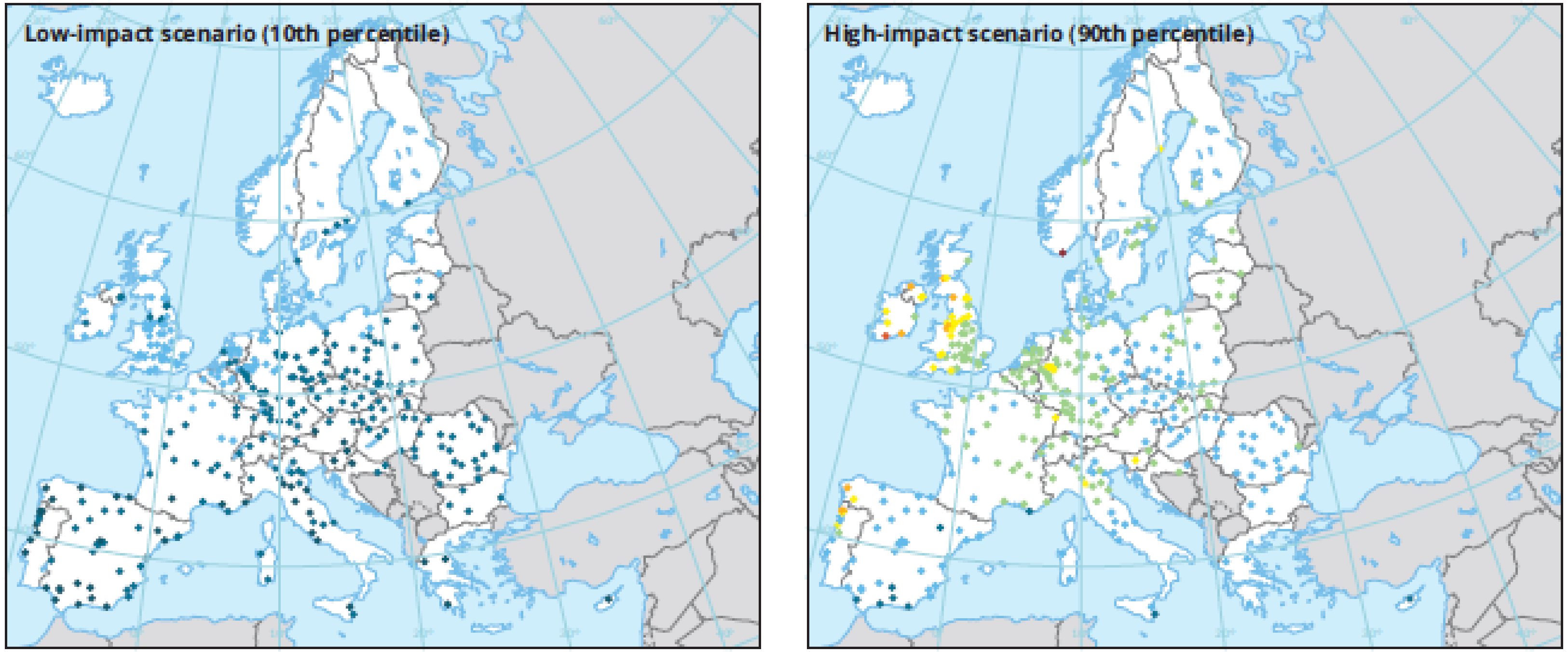
Projected change in annual (left) and summer (right) precipitation, 2071-2100



EEA, 2022. https://www.eea.europa.eu/data-and-maps/figures/projected-changes-in-annual-and-6

River flooding

Map 2.9 Changes in the 10-year high river flow for European cities with large river basins (ratio between 2051-2100 and 1951-2000 flows)



Reference data: ©ESRI

Changes in the 10-year high river flow for European cities with large river basins (ratio between 2051-2100 and 1951-2000 flows)

Ratio between projected future and historical flows

< 0.75 | 0.75-1 | 1-1.25 | 1.25-1.5 | 1.5-1.75 | 1.75-2 | 2-2.25 | > 2.25

0 | 500 | 1 000 | 1 500 km

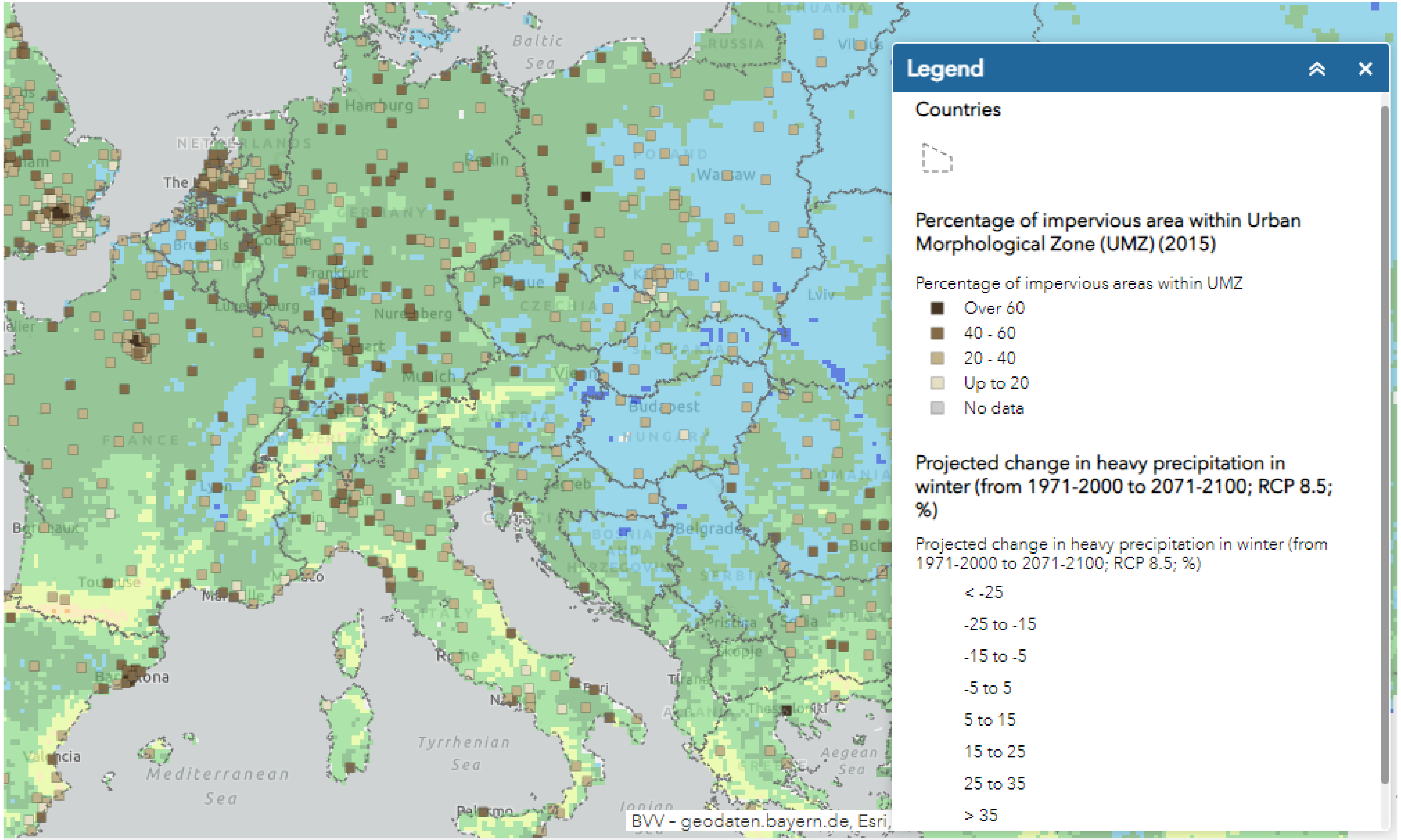
Outside coverage

Notes: The 10-year high flow (Q10) corresponds with the one in 10-year return periods of annual maximum daily discharge. The changes are calculated as the projected 2051-2100 Q10 divided by the 1951-2000 Q10. They are shown for low-impact (10th percentile) and high-impact (90th percentile) scenarios. Based on 50 climate model projections from the CMIP5 (Taylor et al., 2012), for the RCP 8.5 emissions scenario. The digital elevation model Hydro1K was used to delineate river basins for each city. Q10 was estimated using a regression model based on gauge discharge data from the Global Runoff Data Centre (GRDC), and the European daily gridded data set, E-OBS (Haylock et al., 2008). The cities included in the analysis (365) are those that have an upstream river basin larger than 500 km². The 50th percentile (median) scenario is available in the Urban Adaptation Map Viewer; see also Guerreiro et al. (2018).

Source: Adapted from Guerreiro et al. (2018).

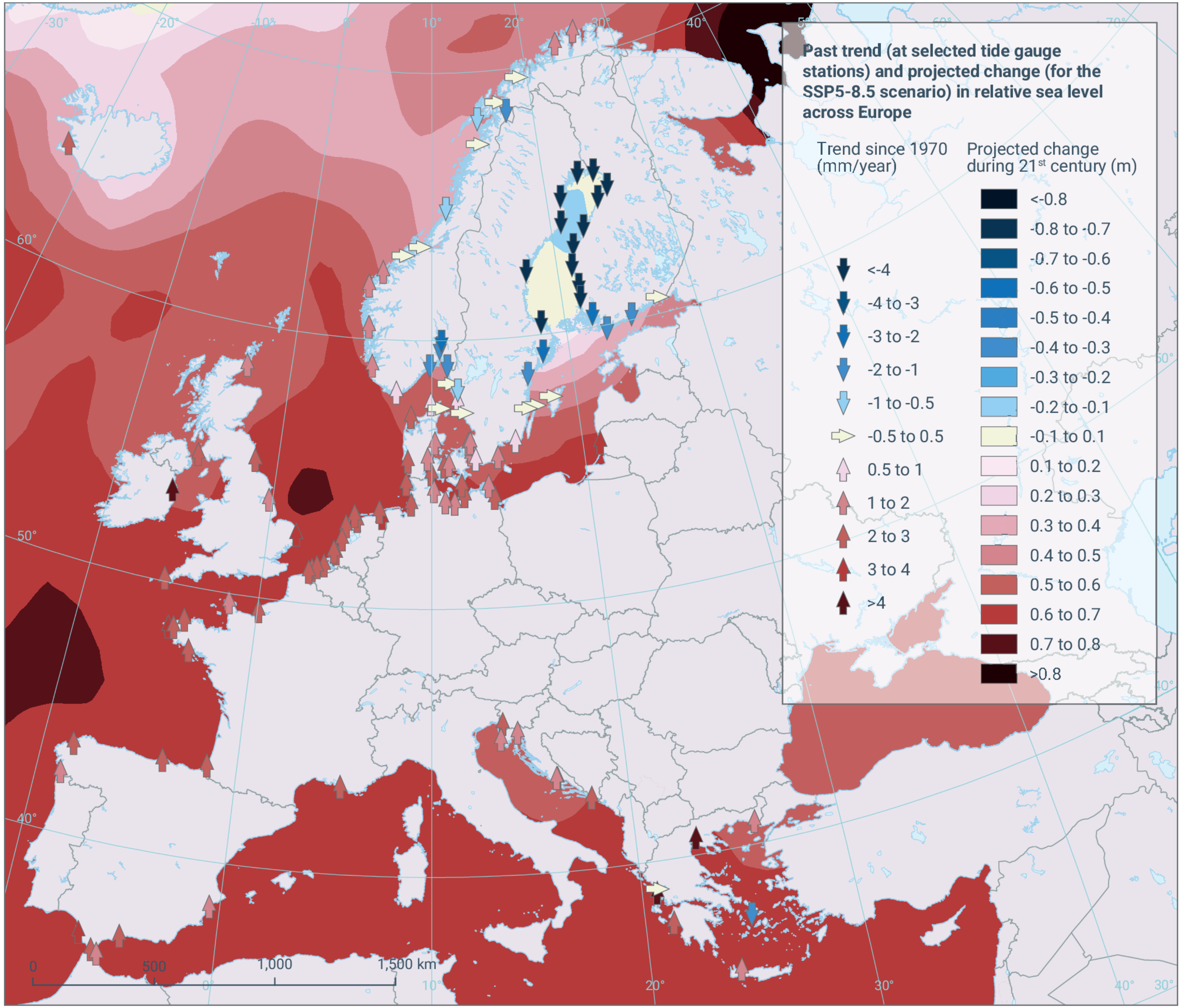
EEA: Urban adaptation in Europe, 2020

Pluvial flooding



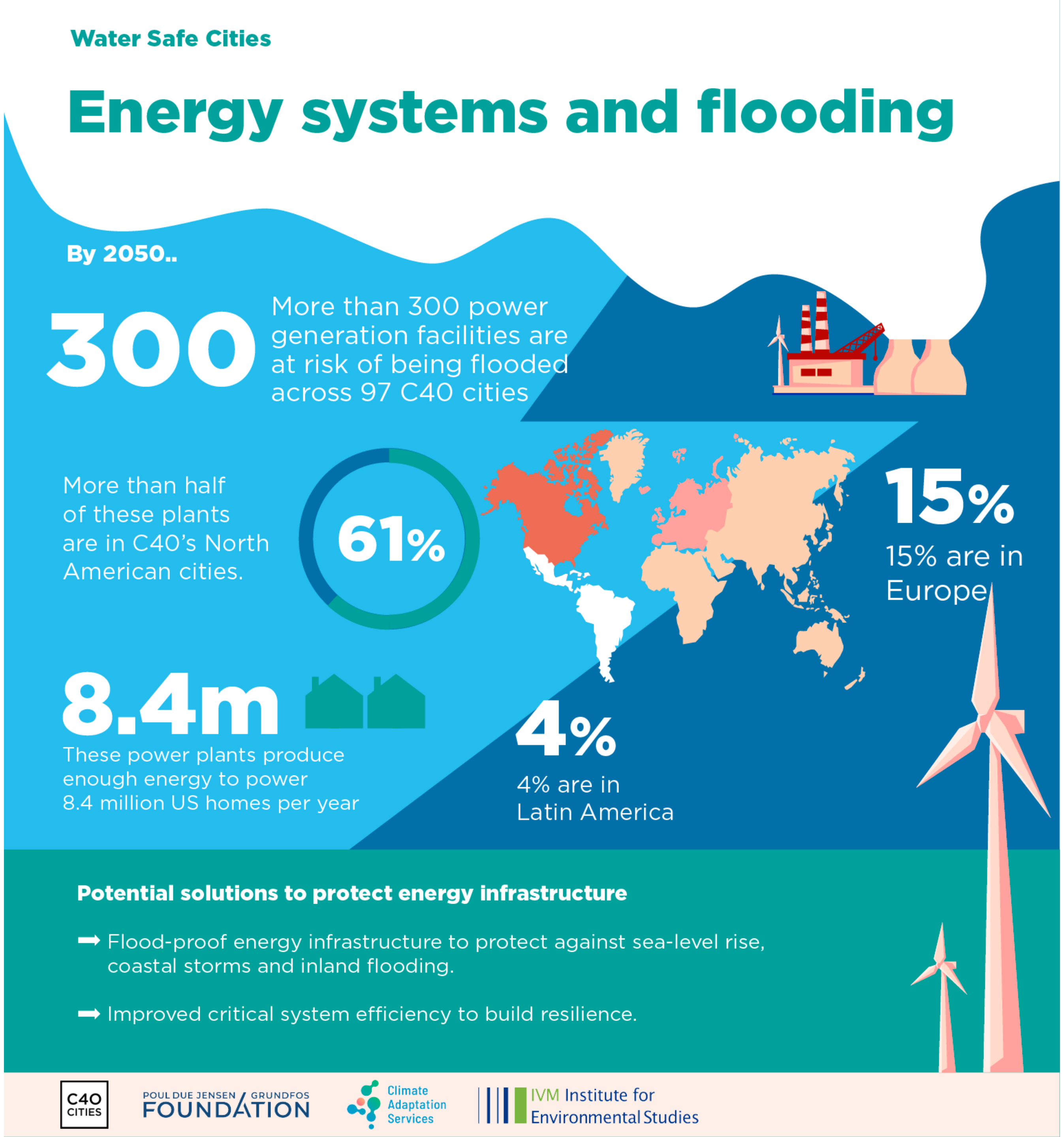
Urban adaptation map viewer https://climate-adapt.eea.europa.eu/en/knowledge/tools/urban-adaptation

Coastal flooding



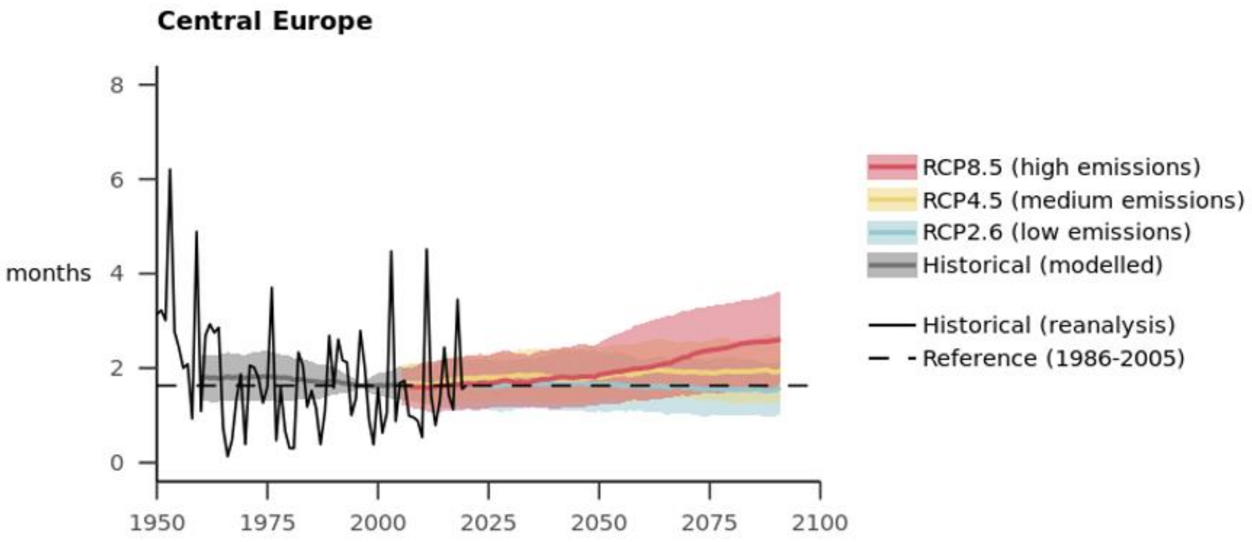
Reference data: © EuroGeographics, © FAO (UN), © TurkStat Source: European Commission – Eurostat/GISCO

EEA, 2024



Water Safe Cities Technical report, C40 cities (2022)

Duration of meteorological droughts



EEA, 2022 https://www.eea.europa.eu/data-and-maps/figures/duration-of-meteorological-droughts

"an exceptional period of water shortage for existing ecosystems and the human population (due to low rainfall, high temperature and/or wind)" (IPCC)

1. **Meteorological drought** – a shortage of rainfall.
2. **Agricultural drought** – a shortage of soil moisture that would otherwise be available for crop and vegetation growth.
3. **Hydrological drought** – a lack of (sub-) surface water, including streams/rivers and roundwater.

C40 cities, 2022

SUMMARY OF GLOBAL NUMBERS

Vulnerability	Time Period	Population Estimate	City Estimate
WATER AVAILABILITY	2050s	Over 650 million people	Over 500 cities

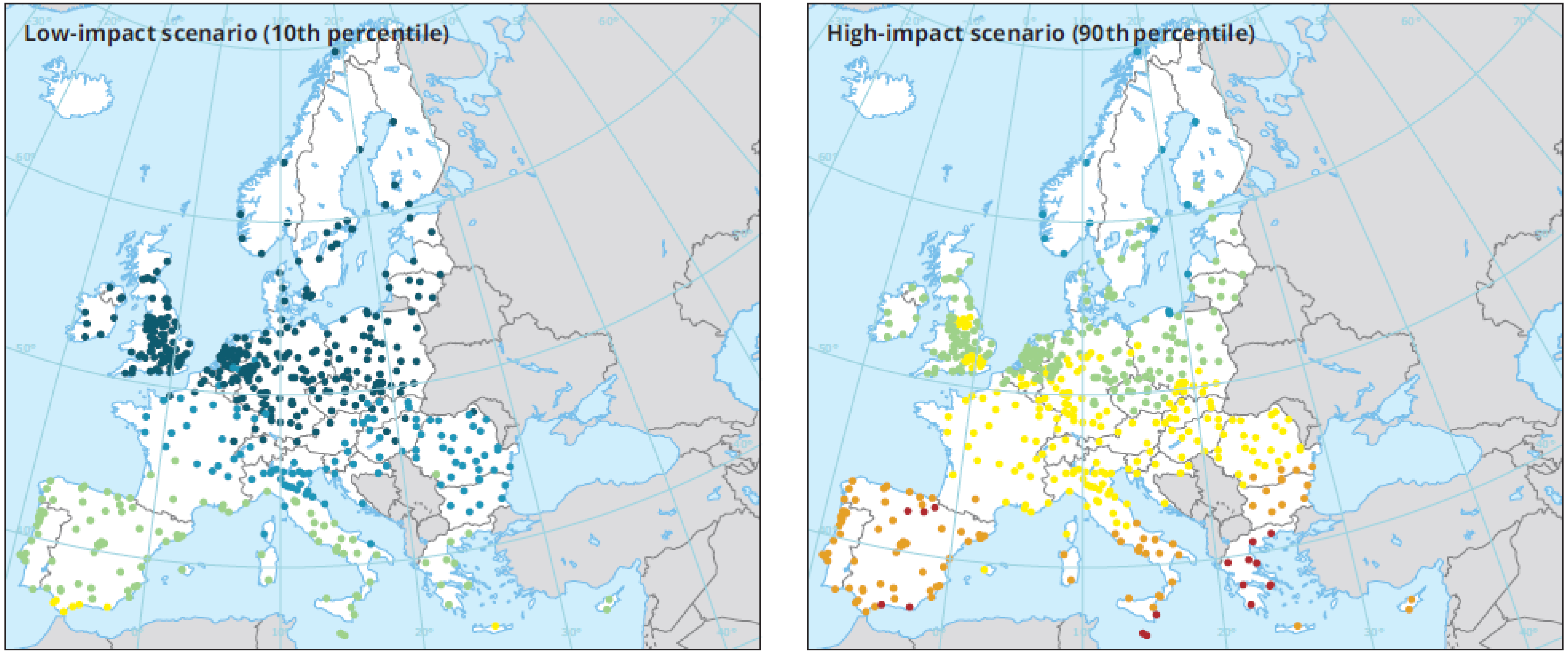
Water Availability: The total number of people living in cities where freshwater availability from stream-flow is projected to decline by at least 10 percent by the 2050s, compared to the present day.

The future we don't want, 2018

System	Attribute or subsystem investigated	
	by impact chains	by data-driven method
Agriculture	Crop yield (irrigated and rain fed separately)	Crop yield (irrigated and rain fed jointly)
Water supply	Unmet household-consumption water demand	Water abstraction for public water supply
Energy	Unmet energy demand by consumers	Hydro and nuclear power production
River transportation	Disruption of industrial and coal-based energy production	Inland transportation of goods
Terrestrial ecosystems	Decreased forest health	Anomaly in net primary production
Freshwater ecosystems	Disruption of environmental water flow necessary to maintain the ecosystem functions	Anomaly in net primary production

Drought atlas, JRC, 2023

Map 2.10 Change factor of maximum drought in 571 European cities between 1951-2000 and 2051-2100



Reference data: ©ESRI

Change factor of maximum drought in 571 European cities between 1951-2000 and 2051-2100

Change factor

< 0.5 | 0.5-1 | 1-2 | 2-5 | 5-10 | > 10

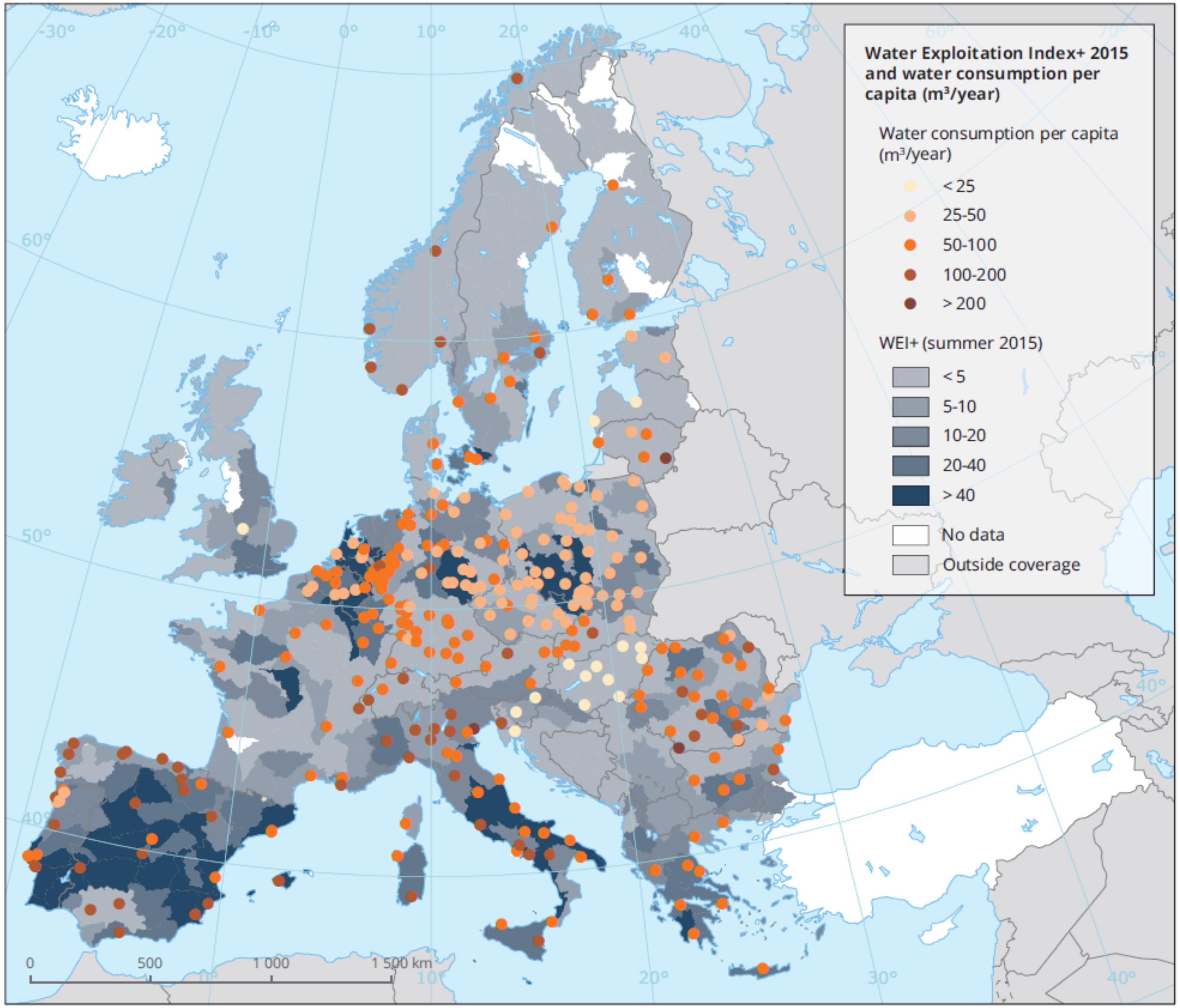
0 500 1 000 1 500 km

Outside coverage

Note: The 12-month scale Drought Severity Index (DSI-12) was used. It is based on cumulative monthly precipitation anomalies, whereby the absolute deficit (in mm) is divided by the mean annual rainfall and multiplied by 100. DSI-12 is a rainfall index and therefore does not account for an increase in drought due to increasing temperatures (and consequently potential evaporation). The map shows the ratio of the maximum DSI-12 in the future to the maximum DSI-12 in the historical period. Based on 50 climate model projections from the CMIP5 (Taylor et al., 2012), in the RCP 8.5 climate scenario. The low-impact scenario (left) refers to the 10th percentile and the high-impact scenario (right) refers to the 90th percentile of projections. Median (50th percentile) scenario can be found in the Urban Adaptation Map Viewer.

Source: Adapted from Guerreiro et al. (2018).

Map 2.11 Pressure on water resources in Europe



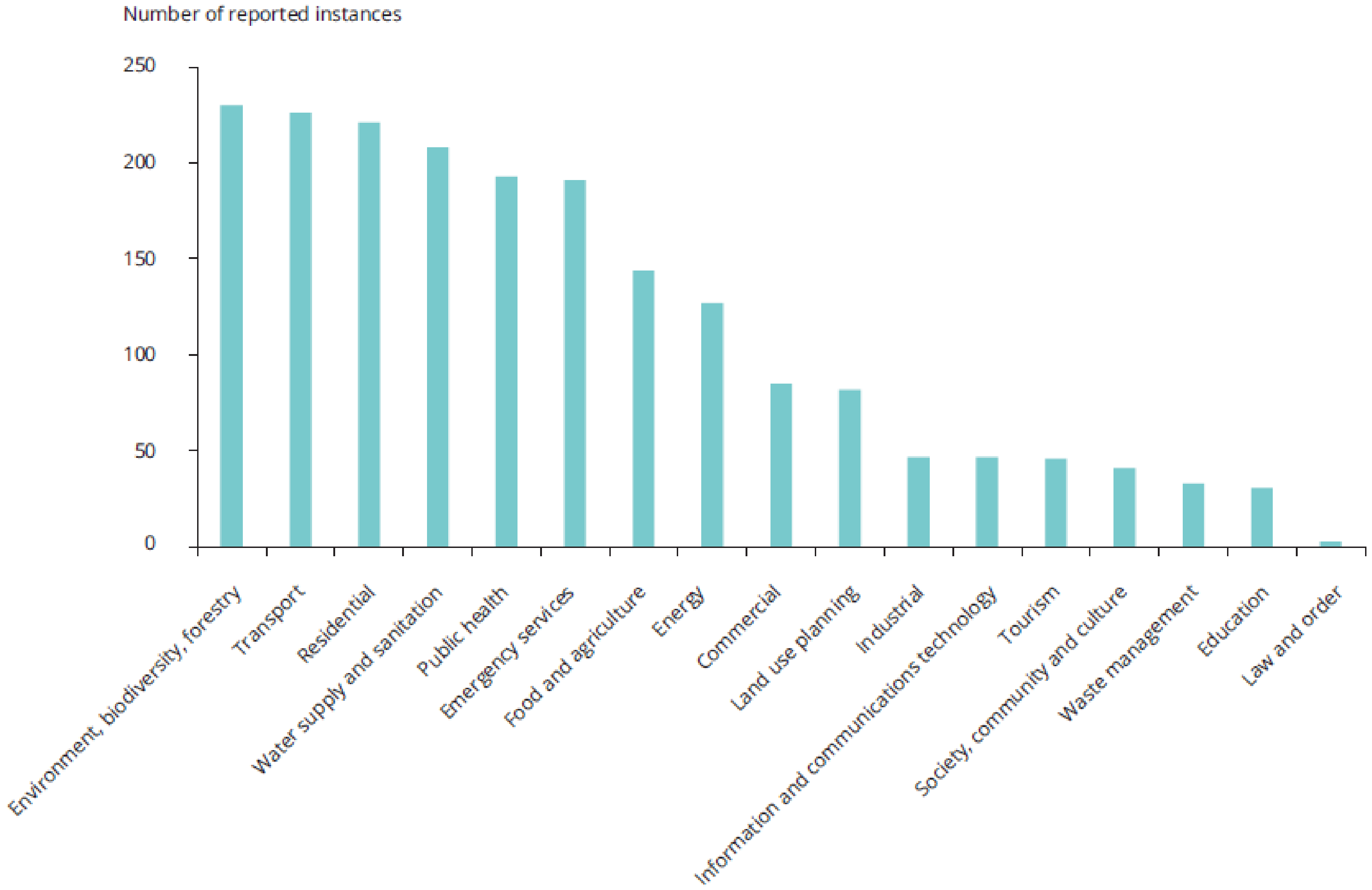
Reference data: ©ESRI

Note: WEI+ is the total use of water as a percentage of renewable freshwater resources. Water consumption for 335 Urban Audit cities (total annual use of water in m³ per capita) is provided for various years (2004-2012), depending on data availability for a given city. See the Urban Adaptation Map Viewer for details. Source: Author's compilation based on EEA (2020e) and Eurostat water consumption statistics.

Source: Author's compilation based on EEA (2020e) and Eurostat water consumption statistics.

Precipitation-related climate risks and adaptation in central EU

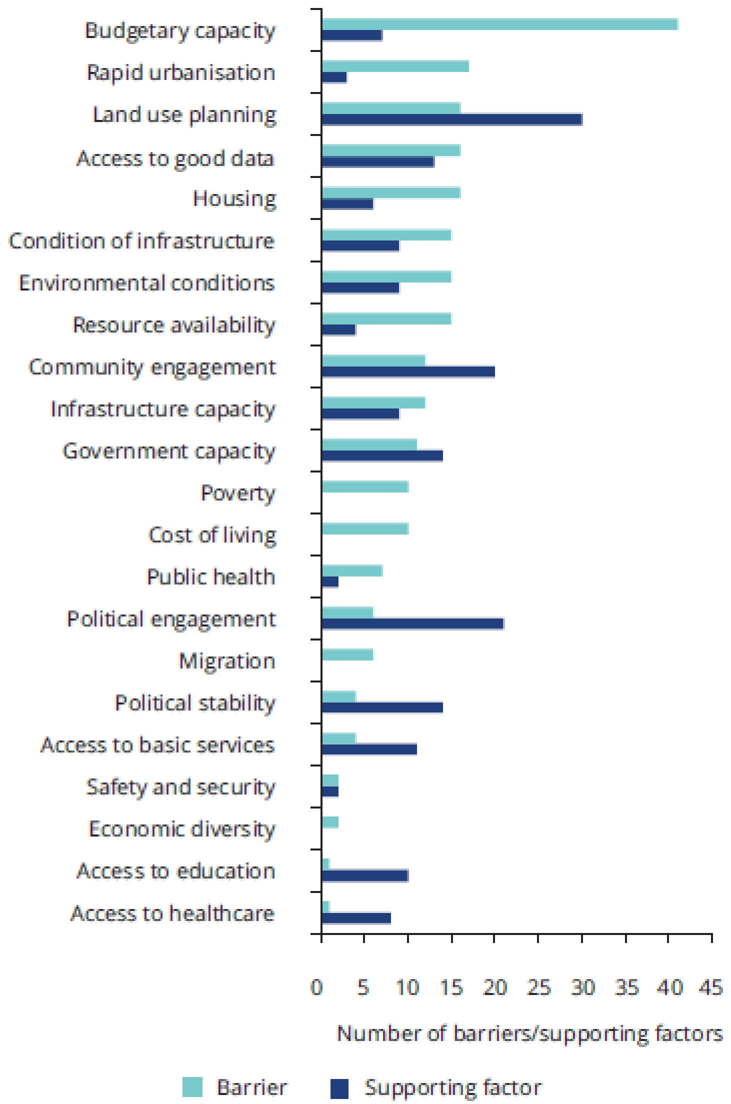
Figure 2.3 **Assets and services expected to be most affected by climate- and weather-related hazards in European cities**



Note: As reported by 163 cities from 26 EEA member and collaborating countries and the United Kingdom. Assets and services could be selected multiple times for various climate hazards.

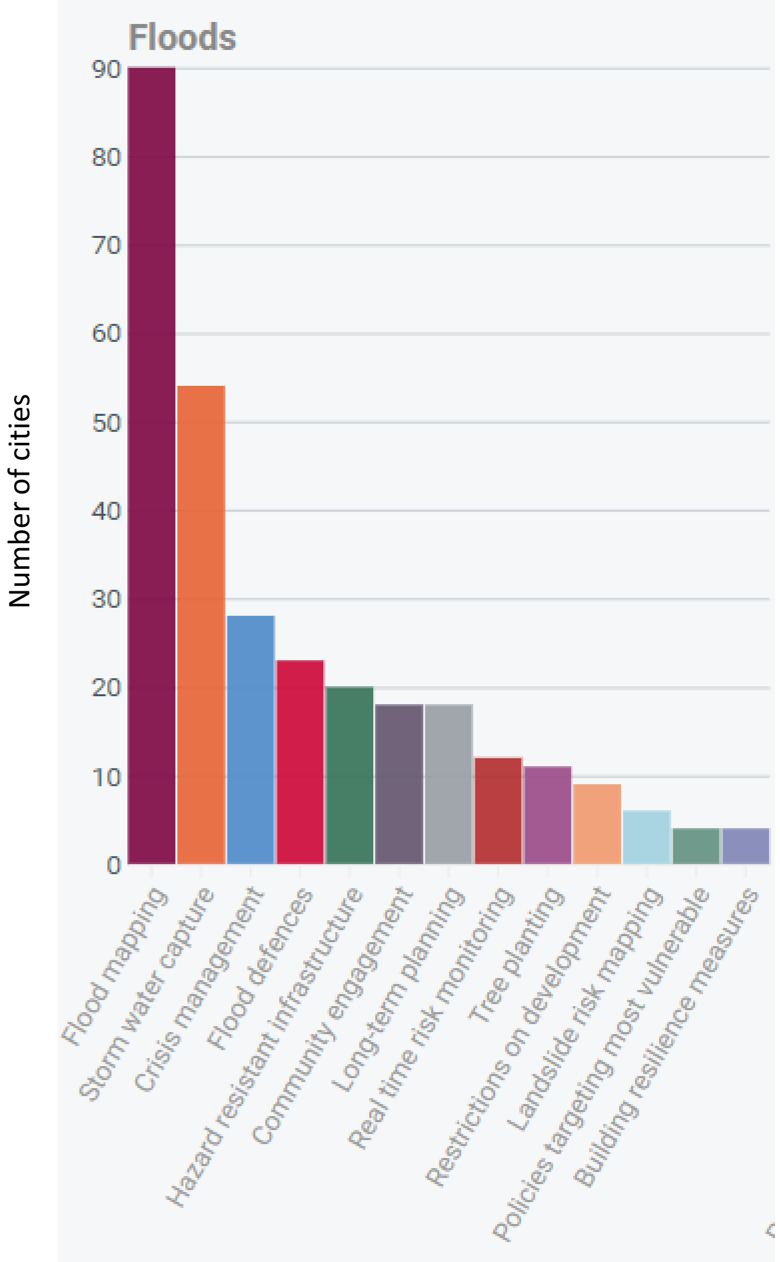
Source: Author's compilation based on analysis of the CDP (2019) database.

Figure 6.1 **Factors influencing cities' ability to adapt to climate change**



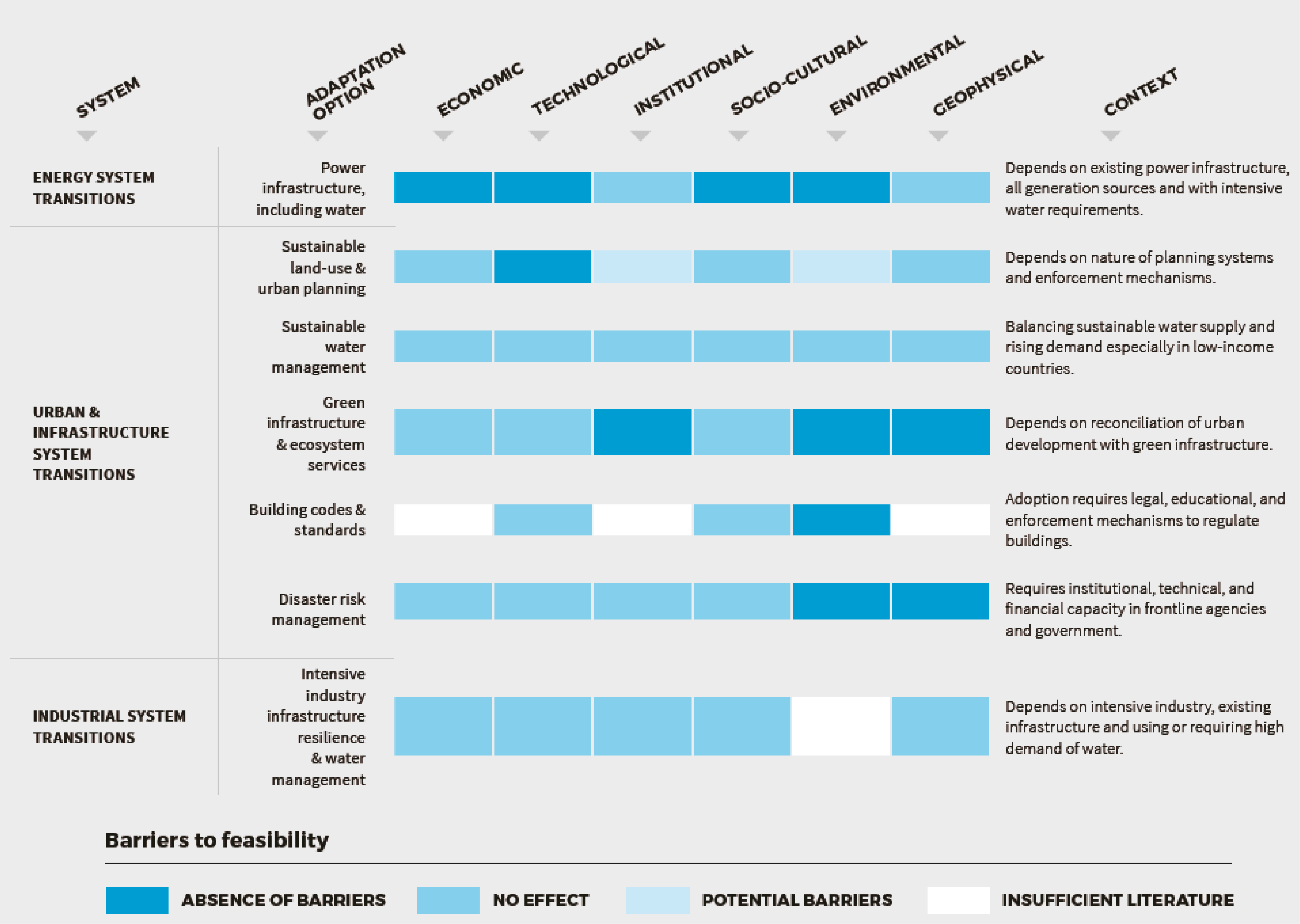
Note: As reported to CDP by 106 cities from 24 EEA member and collaborating countries and the United Kingdom.

EEA: Urban adaptation in Europe, 2020



https://www.cdp.net/en/research/global-reports/cities-at-risk

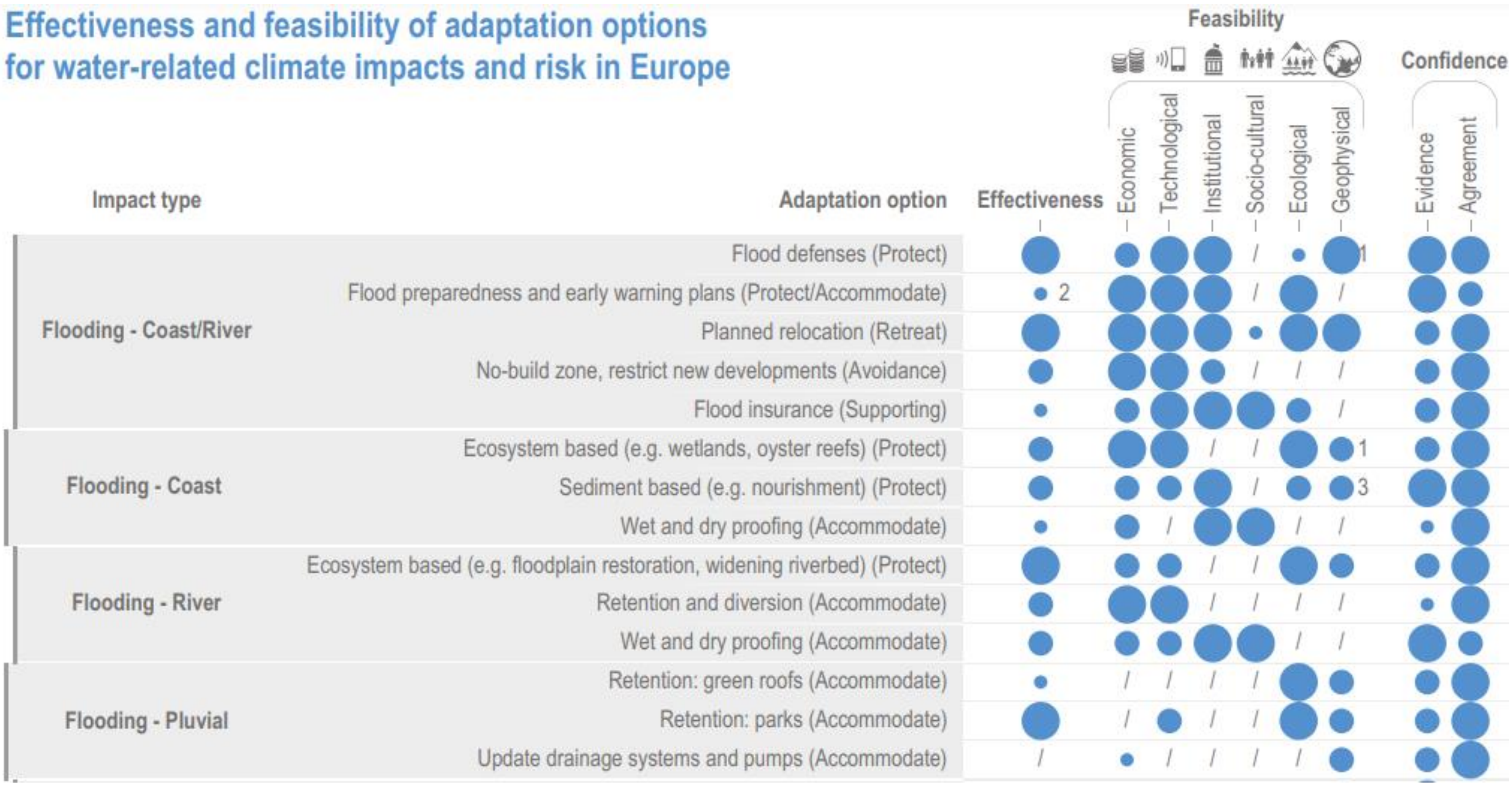
Figure 6. Feasibility Assessment of Urban-Relevant Adaptation Options



Summary for urban Policy Makers, 2018 from IPCC special report on 1.5

Climate risks	Adaptation	Effectiveness outcomes (positive, negative, neutral, mixed, insufficient evidence)				Mitigation	Context specificity	Adaptation adequacy and limits
		For vulnerable people	For at-risk ecosystems	For goals of equity, gender justice	Over time			
Riverine, inland floods	Flood risk management in Western and Central Europe	Mixed	Mixed	Mixed	Mixed	Mixed	Effectiveness depends on geographical location, type of flood hazard, people exposed, prior investments in adaptation and current levels of vulnerability. The effectiveness of early warning systems depends on timing, severity and usability of warnings.	Damages can be significantly reduced even at higher warming (2–4°C) if high levels of adaptation are implemented. However, even when multiple options are implemented, risk of flooding will remain.
Drought, rainfall variability	Climate-smart agriculture in West Africa	Mixed	Positive	Mixed	Insufficient evidence, with potential for positive	Positive	The effectiveness of climate-smart agriculture largely depends on the agroecological conditions, farm size, and intervention type.	Climate-smart agriculture builds capacities to deal with hazards at current warming. However, there is insufficient evidence about how it performs at higher warming levels and how compound hazards might potentially lead to limits being reached early.

UNEP too little, too slow: Adaptation Gap Report 2022



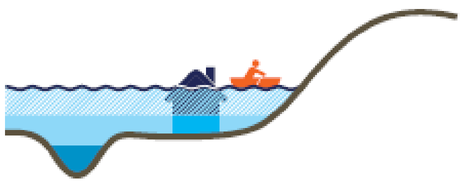
IPCC AR6 WG2 CH. 13.1.4 (2022)

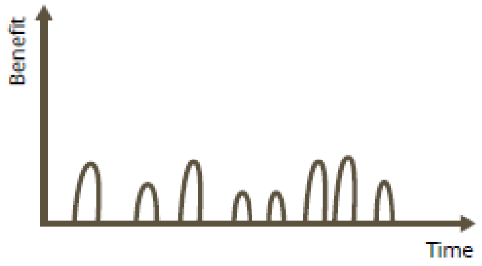
Table 3.3 Dealing with climate change challenges: examples of incremental and transformational approaches

Challenge \ Approach	Incremental measures: optimising conventional measures	Transformational measures: dealing with the challenge in a different way
Flooding	Build more dikes and floodgates	Create space for water; retention areas
	Reinforce existing dikes	Reduce soil sealing to allow natural drainage
	Pump water out	Place infrastructure on higher grounds
	Floodgates at buildings	Retreat from low-lying, potentially flood-prone areas
		Floating buildings and infrastructure
		Develop infrastructure that can be temporarily flooded without any damage (non-sensitive use of ground floors and basements)
Water scarcity and droughts	Serve the demand by getting water from distant regions	Reduce the demand by water-saving appliances in households and buildings
	Water rationing	Reuse water
	Reduce leakages	Establish water-saving behaviours
		Change production using less water
Various	Improve existing governance and behaviour	Changed governance; consumption, behaviour etc.

https://climate-adapt.eea.europa.eu/en/knowledge/tools/urban-adaptation

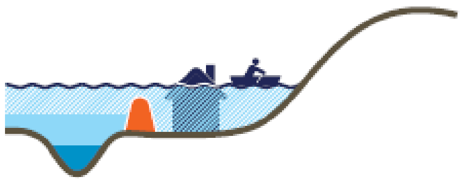
COPING





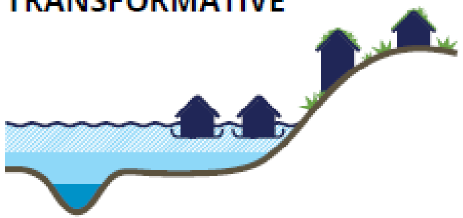
Purely coping approaches bring short-term benefits that decrease to zero with each new disaster. They therefore imply high costs over time.

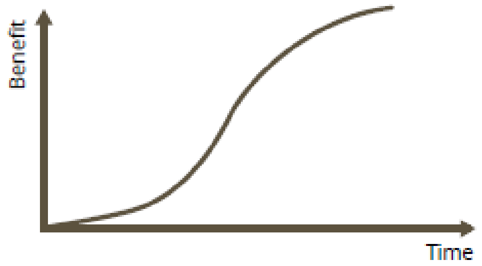
INCREMENTAL



Incremental approaches work effectively up to certain risk levels. Benefits level off over time and higher risk levels will require additional coping.

TRANSFORMATIVE





Transformative approaches need some time and efforts at the beginning but then benefits increase and are stable. Very little coping is needed to buffer extremely high risk levels.

Normal water level

Water level — 1/50 years flood event

Water level — 1/100 years flood event

Vir: EEA, 2016

Coastal protection strategies in small Danish cities

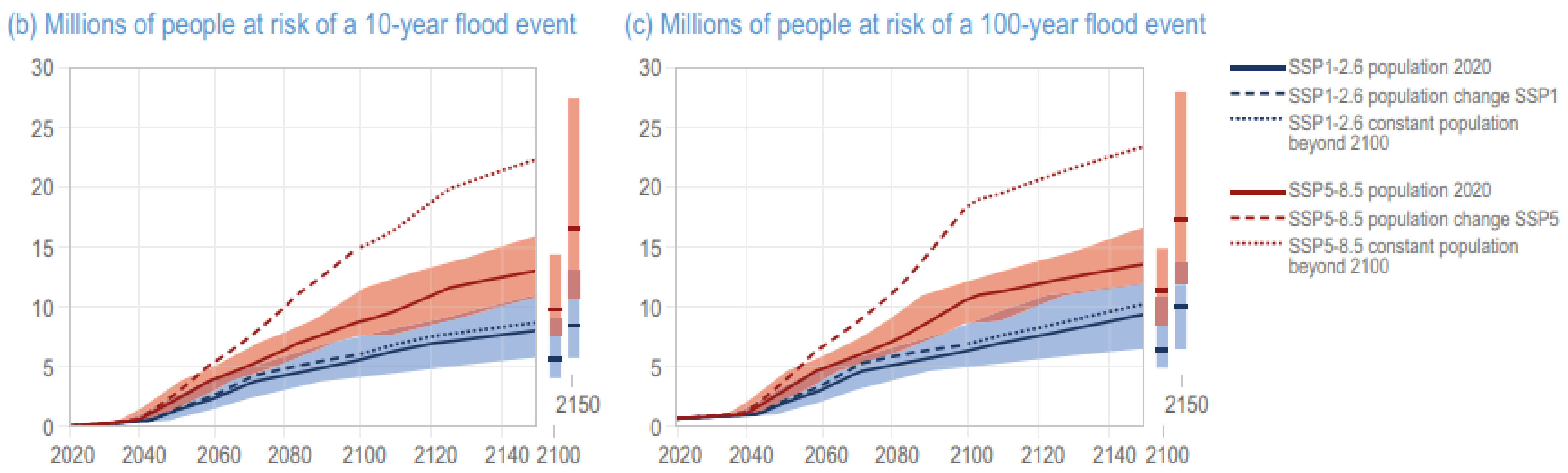
To date, the wall has protected Lemvig against coastal flooding on at least two occasions, saving the city from damage costing about DKK 30 million (EUR 4 million). The cost of implementation was DKK 18 million (EUR 2.4 million). The wall is designed as an assembly kit that can be implemented in other coastal cities.

'Le Mur' protecting Lemvig harbour © Mads Krabbe

Detail of the wall © Lemvig municipality

Sources: Global Opportunity Explorer (2018a, 2018b); https://kanalbyen.dk; https://www.danskeark.dk/content/le-mur; and direct communication from Lemvig municipality.

EEA: Urban adaptation in Europe, 2020



(b) projected population at risk to experience a 1-in-10-year coastal flood event under RCP2.6-SSP1 and RCP8.5-SSP5 assuming present protection and population levels, as well as population change according to, respectively, SSP1 and SSP5, based on Merkens (2016);

(c) projected population at risk to experience a 1-in-100-year coastal flood event under RCP2.6-SSP1 and RCP8.5-SSP5, assuming the present protection and population levels, as well as population change according to, respectively, SSP1 and SSP5, based on Merkens (2016) (based on Haasnoot et al., 2021b).

IPCC AR6 WG2 CH. 13.1.4 (2022)

Adaptation measures – droughts (RESIN, 2018)

- rainwater management
- waste water reuse
- fresh water production through desalination and
- water demand management

Table 3.2 Unit costs of drought measures implemented in Barcelona

Measure type	Measure	Unit costs (EUR/m³)
Demand measures: communication and awareness-raising campaigns about water saving	No welfare loss consideration	0.03
	Welfare loss consideration	1.36
Supply measures	Water shipping	32.53
	Headwater cisterns	2.3
Structural measures	Well recovery and enhancement of groundwater extraction	0.18
	Enlargement of existing desalination plant	0.61-1.30

Note: Unit cost reflects how costly it is for each of the measures to provide one additional cubic metre. Welfare losses are costs to society, including costs to producers and consumers, and taxation.

Source: Adapted from Martin-Ortega et al. (2012).

EEA: Urban adaptation in Europe, 2020

Box 3.14 Polish cities subsidise small-scale rainwater retention

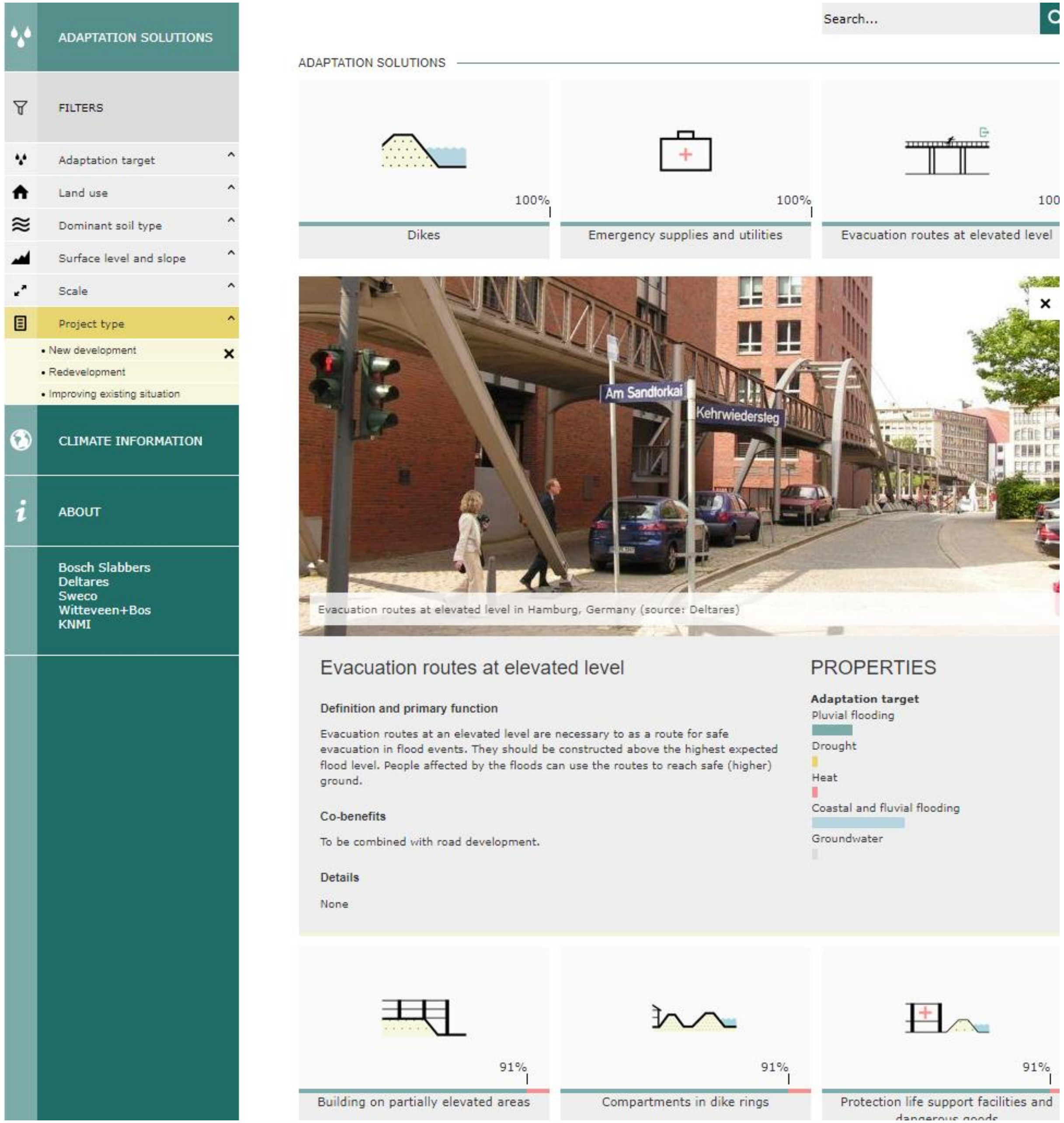
In acknowledgement of the increasing frequency and intensity of both droughts and heavy precipitation events, several Polish cities recognise the importance of small-scale rainwater retention. Subsidies are offered to homeowners for rainwater collection systems. The aims of these programmes are to reduce the amount of municipal water used for gardening, cleaning or flushing toilets, and to limit the pressure on the sewerage systems from heavy precipitation events, and thus lower the risk of urban flooding.

In Kraków, private water retention has been subsidised since 2014. Between 2014 and 2018, the city supported 384 installations for rainwater collection and reuse, investing over PLN 1.8 million. Individuals, housing cooperations and businesses can apply for subsidies covering 50 % of the rainwater collection system costs, with a ceiling of PLN 5 000 (around EUR 1 100). In 2019, the city committed PLN 500 000 to the programme. Between January and the end of July 2019, 97 applications were made.

In Wrocław, within the Złap deszcz ('Catch the rain') programme, since August 2019 residents have been able to apply for reimbursements of 80 % of the costs of rainwater collection through either free-standing or underground containers, with a limit of PLN 5 000 (around EU 1 100). The programme is organised by the Wrocław city council in collaboration with the municipal water and sewerage company and the water knowledge centre Hydropolis. To raise awareness of the programme, the municipal water and sewerage company organised a competition, in which 100 rainwater barrels of 210 litres could be won by those sending photographs illustrating their 'eco-creativity'.

Sources: Ciszak (2019); City of Krakow (2019).

EEA: Urban adaptation in Europe, 2020



https://www.climateapp.nl/

Component 1: selection of feasible measures

To start the selection of feasible measures, one or more options for each of the six filters needs to be selected. The options can best be selected in based on a specific project. Based on the input a ranking of suitable measures is presented.

Component 2: specific information on measures

It is possible to get more information on each individual adaptation measure included in the app. For this just search, click or press the specific measure.

Component 3: specific climate information

For three cities specific climate information is provided. This information can be accessed through the climate information button.

Climate risk and vulnerability assessment - Training guide for cities, CDP 2022.
https://cdn.cdp.net/cdp-production/comfy/cms/files/files/000/006/058/original/CDP_Resourcepack.pdf

Bednar-Friedl, B., R. Biesbroek, D.N. Schmidt, P. Alexander, K.Y. Børsheim, J. Carnicer, E. Georgopoulou, M. Haasnoot, G. Le Cozannet, P. Lionello, O. Lipka, C. Möllmann, V. Muccione, T. Mustonen, D. Piepenburg, and L. Whitmarsh, 2022: Europe. In: *Climate Change 2022: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 1817–1927, doi:10.1017/9781009325844.015.

The future we don‘t want, 2018. https://www.c40.org/what-we-do/scaling-up-climate-action/adaptation-water/the-future-we-dont-want/

EEA: Urban adaptation in Europe, 2020. https://www.eea.europa.eu/publications/urban-adaptation-in-europe

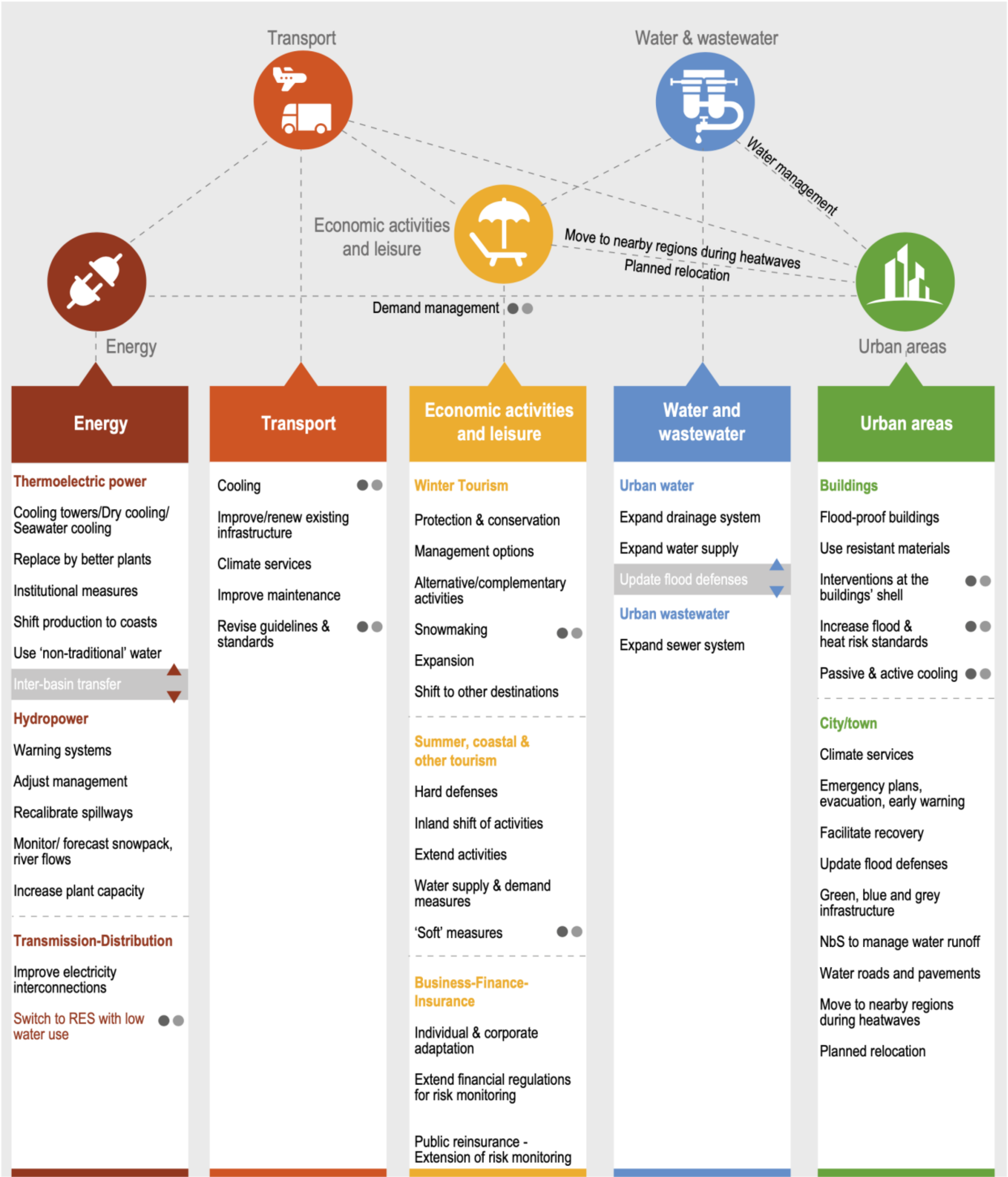
Summary for urban Policy Makers, 2018 from IPCC special report on 1.5

Water Safe Cities Technical report, C40 cities (2022) https://storymaps.arcgis.com/stories/75508f9fac8c43bda366ae545fb60ec8

Global and European sea level rise, EEA, 2024. https://www.eea.europa.eu/en/analysis/indicators/global-and-european-sea-level-rise

Rossi, L., Wens, M., De Moel, H., Cotti, D., Sabino Siemons, A., Toreti, A., Maetens, W., Masante, D., Van Loon, A., Hagenlocher, M., Rudari, R., Naumann, G., Meroni, M., Avanzi, F., Isabellon, M. and Barbosa, P., European Drought Risk Atlas, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/608737, JRC135215.

Adaptation options for cities, settlements and key infrastructure



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Box 13.3 | Climate Resilient Development Pathways in European Cities

Climate resilient development (CRD) in European cities offers synergies and co-benefits from integrating adaptation and mitigation with environmental, social and economic sustainability (Geneletti and Zardo, 2016; Grafakos et al., 2020). Climate networks (e.g., Covenant of Mayors), funding (e.g., Climate-KIC), research programmes (e.g., Horizon Europe), European and national legislation, international treaties and the identification of co-benefits contribute to the prioritisation of climate action in European cities (Heidrich et al., 2016; Reckien et al., 2018; CDP, 2020). Still, mitigation and adaptation remain largely siloed and sectoral (Heidrich et al., 2016; Reckien et al., 2018; Grafakos et al., 2020). An assessment of the integration of mitigation and adaptation in urban climate-change action plans in Europe found only 147 cases in a representative sample of 885 cities (Reckien et al., 2018).

In European cities, CRD is most evident in the areas of green infrastructure, energy-efficient buildings and construction, and active and low-carbon transport (Pasimeni et al., 2019; Grafakos et al., 2020). Nature-based Solutions, such as urban greening, often integrate adaptation and mitigation in sustainable urban developments and are associated with increasing natural and social capital in urban communities, improving health and well-being, and raising property prices (Geneletti and Zardo, 2016; Pasimeni et al., 2019; Grafakos et al., 2020). Barriers to CRD in European cities include limitations in: funding, local capacity, guidance documents and quantified information on costs, co-benefits and trade-offs (Grafakos et al., 2020). Pilot projects are used to initiate CRD transitions (Nagorny-Koring and Nochta, 2018). Malmö (Sweden) and Milan (Italy) are two examples to illustrate the strategies and challenges of two European cities attempting to implement CRDP.

Malmö (population 300,000): Since the 1990s, Malmö has been transitioning towards an environmentally, economically and socially sustainable city, investing in eco-districts (redeveloped areas that integrate and showcase the city's sustainability strategies) and adopting ambitious adaptation and mitigation targets. The city has focused on energy-efficient buildings and construction, collective and low-carbon transportation, and green spaces and infrastructure (Anderson, 2014; Malmo Stad, 2018). Malmö has developed creative implementation mechanisms, including a 'climate contract' between the city, the energy distributor and the water and waste utility to co-develop the climate-smart district, Hyllie (Isaksson and Heikkinen, 2018; Kanters and Wall, 2018; Parks, 2019). Flagship eco-districts play a central role in the city's transition, in the wider adoption of CRD and in securing implementation partners (Isaksson and Heikkinen, 2018; Stripple and Bulkeley, 2019). The city has also leveraged its status as a CRD leader to attract investment. The private sector views CRD as profitable, due to the high demand and competitive value of these developments (Holgersen and Malm, 2015). Malmö adopted the SDGs as local goals and the city's Comprehensive Plan is evaluated based on them, for example, considering gender in the use, access and safety of public spaces, and emphasising development that facilitates climate-resilient lifestyles (Malmo Stad, 2018). Malmö also engages stakeholders via dialogue with residents, collaboration with universities and partnerships with industry and service providers (Kanters and Wall, 2018; Parks, 2019). Despite measurable and monitored targets, and supportive institutional arrangements, sustainability outcomes for the flagship districts have been tempered by developers' market-oriented demands (Holgersen and Malm, 2015; Isaksson and Heikkinen, 2018) and there is limited low-income housing in climate-resilient districts (Anderson, 2014; Holgersen and Malm, 2015).

Milan (population 1.4 million): Milan is taking a CRD approach to new developments (Comune di Milano, 2019). From 2020, new buildings must be carbon neutral and reconstructions must reduce the existing land footprint by at least 10%. The Climate and Air Plan (CAP) and the city's Master Plan (Comune di Milano, 2019) focus on low-carbon, inclusive and equitable development. The CAP is directed at municipal and private assets, and individual- to city-scale actions. In 2020, Milan released a revised Adaptation Plan and the Open Streets Project to ensure synergies between the COVID-19 response and longer-term CRD. Examples include strengthening neighbourhood-scale disaster response and reallocating street space for walking and cycling (Comune di Milano, 2020). Milan emphasises institutionalisation of CRD via a dedicated resilience department, and through active participation in climate networks and projects that support learning and exchange. Climate network commitments are cited in the city's Master Plan and CAP guidelines as driving more ambitious deadlines and emissions targets (Comune di Milano, 2019). Implementation of Milan's plans remains a challenge, despite dedicated resources and commitment.

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	Coping	Incremental adaptation	Transformational adaptation
Aim	Restore current way/ quality of life after disaster (disaster risk management) Reduce negative impact of disaster	Includes aims of 'coping'. In addition: • protect current way/quality of life under changed external conditions; • prevent negative impact of disaster	Includes aims of 'coping' and 'incremental'. In addition: improve/change way/quality of life under changed external conditions
Management	Reactive management of change, focusing on current conditions	Reactive management of change, focusing on current conditions Management of change is focused on finding ways to keep the present system in operation	Foreseen, planned management of change Management of change includes questioning the effectiveness of existing systems and processes
Time horizon	Cope with current disaster Consider current risk levels	Forward-looking, short to medium time horizon; focus on current conditions and short-term change; future uncertainty is not acknowledged May be sufficient for low levels of change (e.g. 1.5–2 °C)	Forward-looking long-term vision; focus on future and long-term change; uncertainty in the future is acknowledged and built into decision-making Preparedness for higher levels of change (e.g. 4–6 °C)
Planning	Disaster driven/coping with consequences Mainly intermittent Emergency budget finance Action-focused stakeholder involvement mostly of professionals Prevailing instrument: disaster risk plan	Opportunity- and needs-based implementation Sustained over urban management cycles Regular but limited budget allocation Project-focused involvement of stakeholders immediately addressed by measure Prevailing instruments: zoning plan, building code	Programme-based implementation Strategically planned according to the systemic, long-term perspective Sustained over long-term urban development programme and management Funding development and sustained financing streams linked to long-term planning policies Broad and integrating involvement of stakeholders in planning Prevailing instrument: sustainable urban development programme
Scale/ integration	Sectoral and local orientation with little connection to larger area (watershed, region, country) High risk of maladaptation	Smaller, discrete, within-system changes, mainly sectoral and local orientation with modest connection to larger area (watershed, region, country) Using some opportunities for joint benefits Medium risk of maladaptation	System-wide or multisystem perspective Integrating climate mitigation and adaptation Integrated across environmental and socio-economic sectors (climate change adaptation is a natural part of urban sustainable development) and different levels of governance Explicitly taking into account external services and possibilities to induce changes elsewhere that have a beneficial effect on the city Low risk of maladaptation
Dealing with lock-ins and uncertainty	Possible lock-ins into unsustainable pathways under future conditions Ignore uncertainty	Possible lock-ins into unsustainable pathways related to long-term changes Partly deal with uncertainty	Avoid lock-ins into unsustainable pathways Stay flexible, deal with uncertainty
Dealing with change	Change seen as a risk Applies known and trusted technologies and approaches; lessons learned from past experience	Change seen as a risk Applies known trusted technologies and methods and increases their efficiency	Change seen as an opportunity Fundamental structural changes/going beyond efficiency gains Niche development Explores alternative, innovative solutions (solve problems differently) in replacing or complementing traditional solutions

Source: EEA, based on Lonsdale et al., 2015.