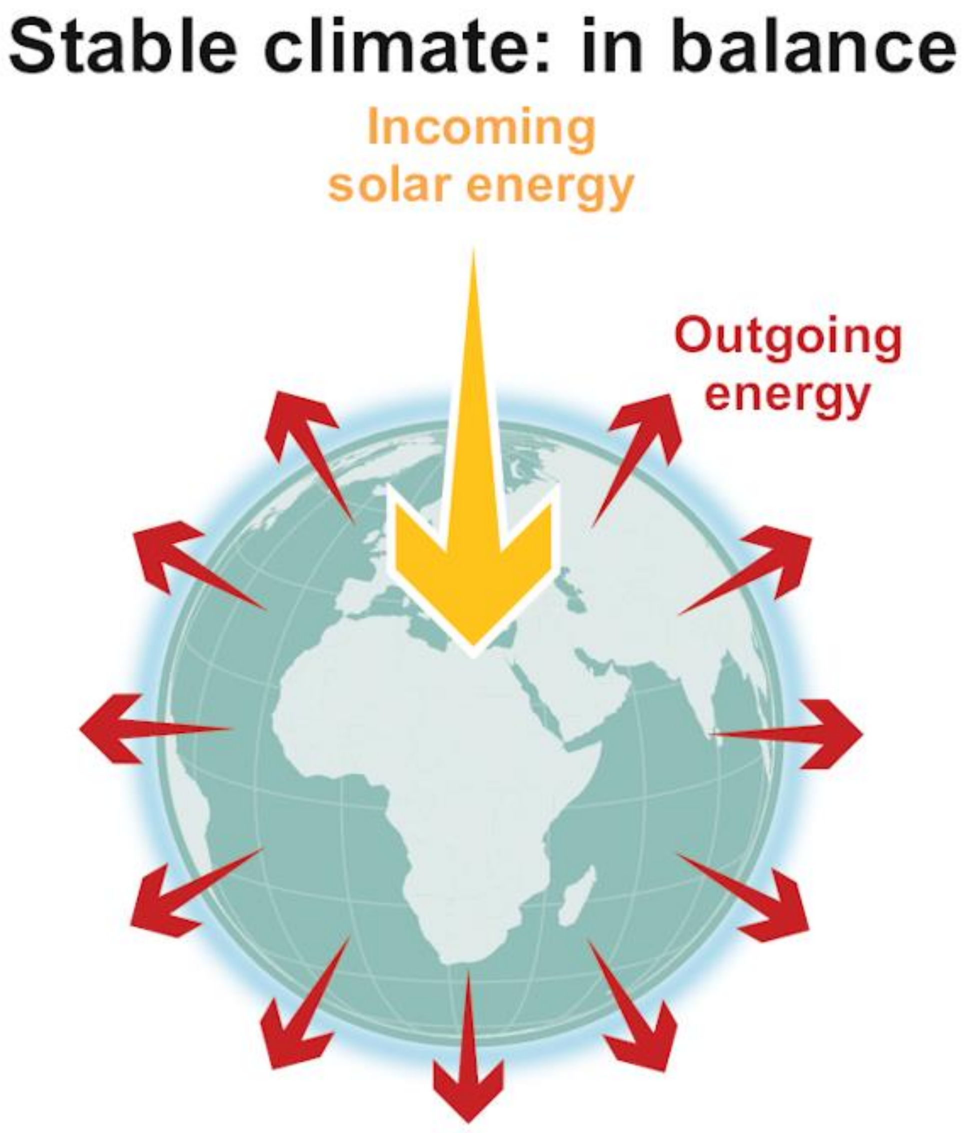
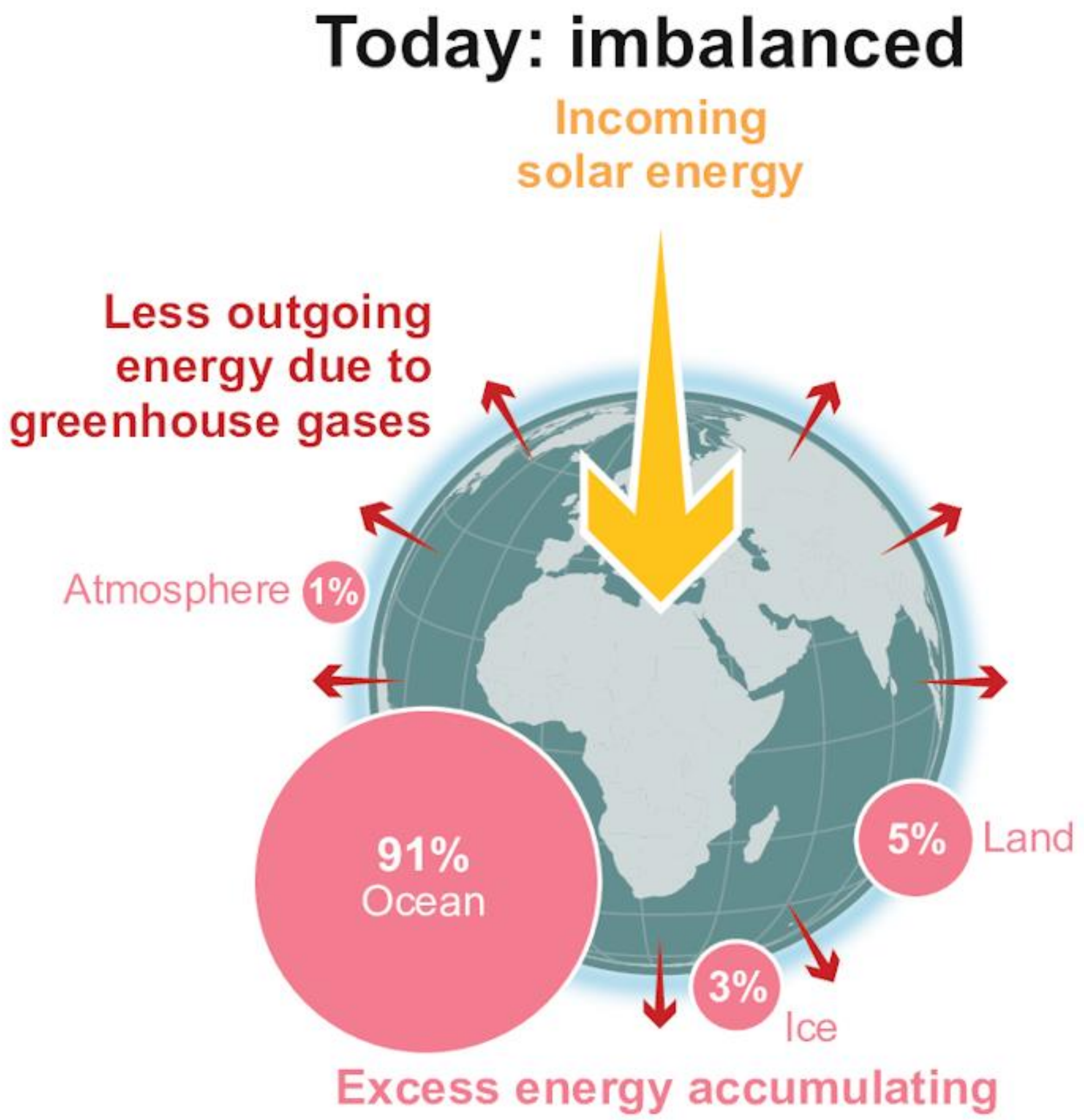
climate is changing – what about us?

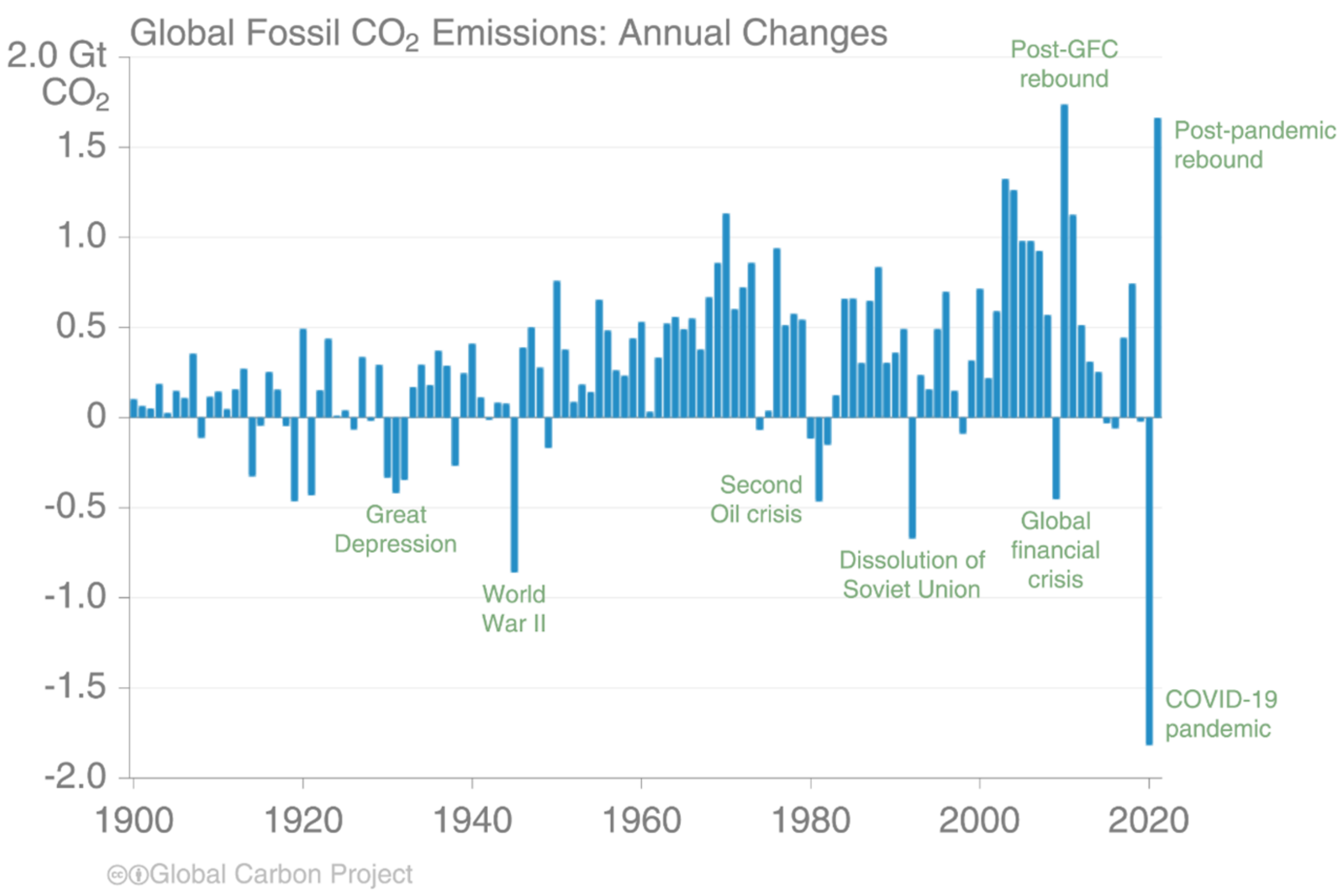
Tjaša Pogačar, UL Biotechnical Faculty, Slovenia

What is climate change?

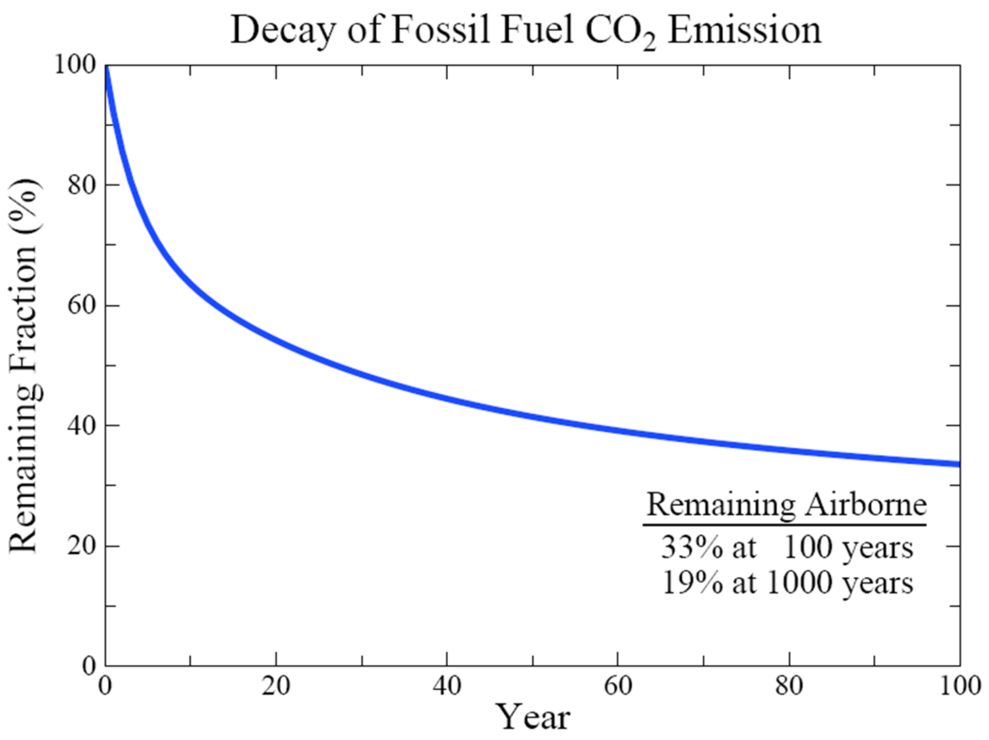


IPCC AR6, WG1 2021

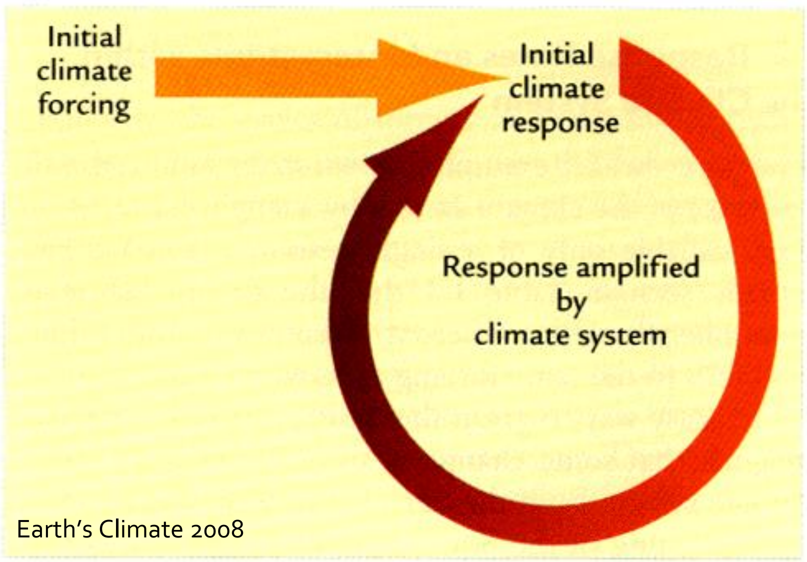




Global Fossil CO_2 Emissions: Annual Changes
2.0 Gt CO_2
1.5
1.0
0.5
0
-0.5
-1.0
-1.5
-2.0
1900
1920
1940
1960
1980
2000
2020
Great Depression
World War II
Second Oil crisis
Dissolution of Soviet Union
Global financial crisis
Post-GFC rebound
Post-pandemic rebound
COVID-19 pandemic
Global Carbon Project



Decay of Fossil Fuel CO_2 Emission
Remaining Fraction (%)
Year
0
20
40
60
80
100
Remaining Airborne
33% at 100 years
19% at 1000 years



Initial climate forcing
Initial climate response
Response amplified by climate system
Earth's Climate 2008

High energy use and dense populations – the city is a CO_2 hotspot

1. The main contributing sectors are:

2. Urbanization will continue in the future, and this process will increase emissions...

3. ...unless cities take actions to reduce emissions through urban planning, technologies and behavioral changes.

Altogether, cities account for **more than 70%** of man made fossil fuel CO_2 emissions.

Cities emissions vary depending on land use, energy consumption and a variety of socioeconomic and geographical factors.

The Global Carbon Project compiled a unique dataset of CO_2 emissions and socioeconomic variables from **343 global cities**.

This data will help scientists and policy-makers **explain the role of socioeconomic drivers** in cities' emissions.

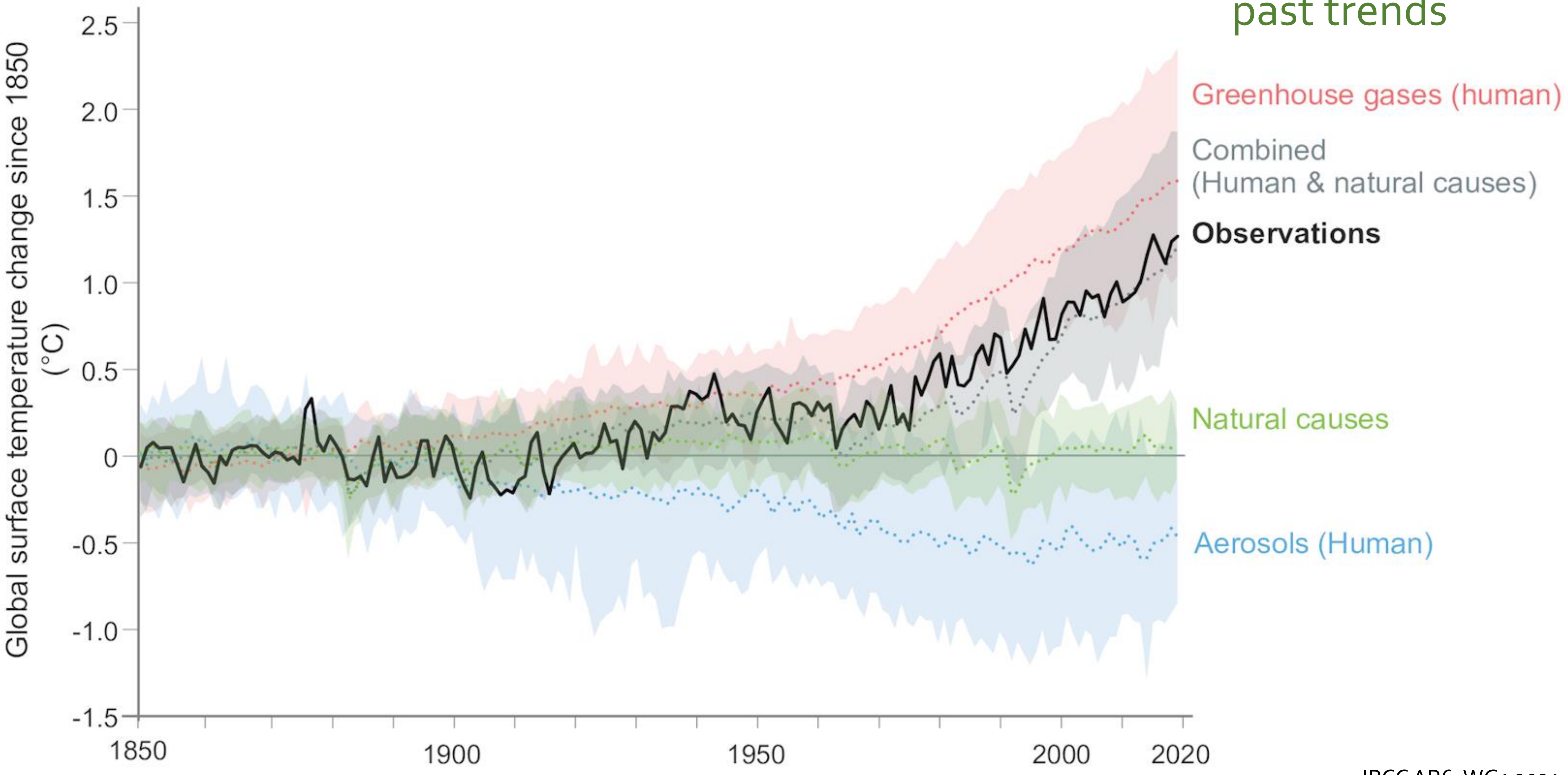
GLOBAL CARBON PROJECT

CDP

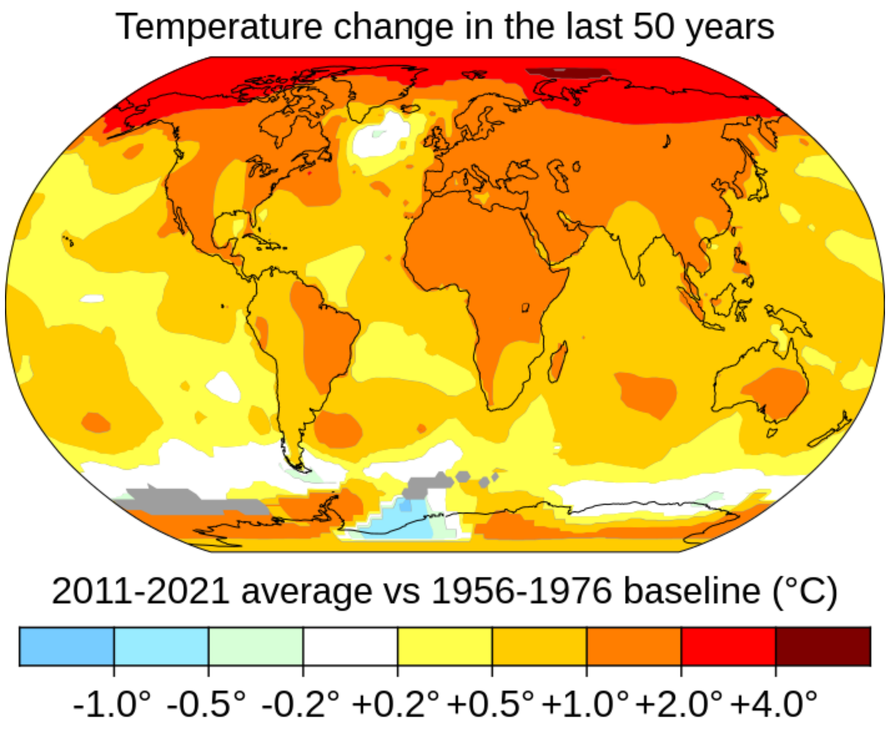
FONDATION BNP PARIBAS

Observed warming (1850-2019) is only reproduced in simulations including human influence.

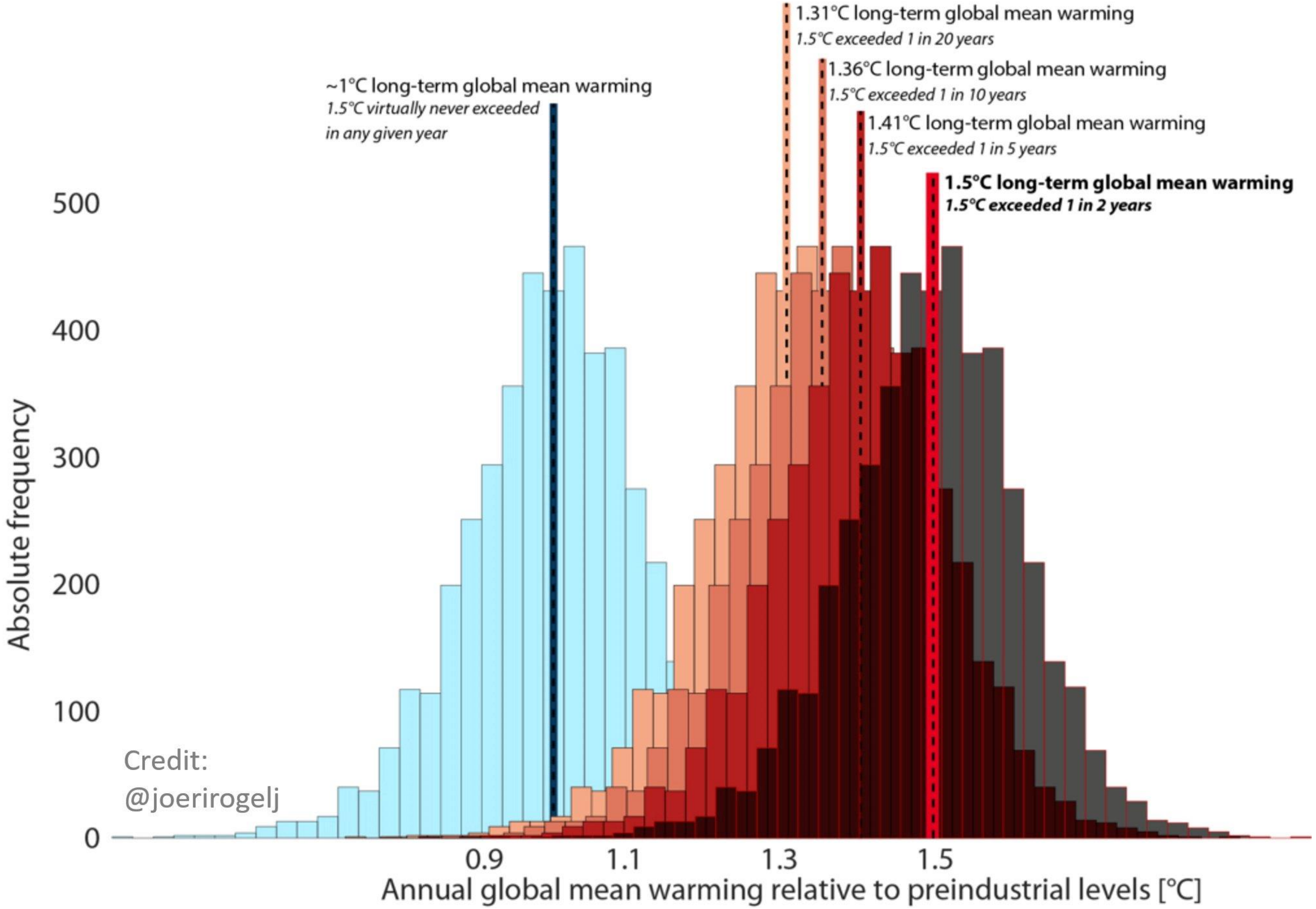
past trends



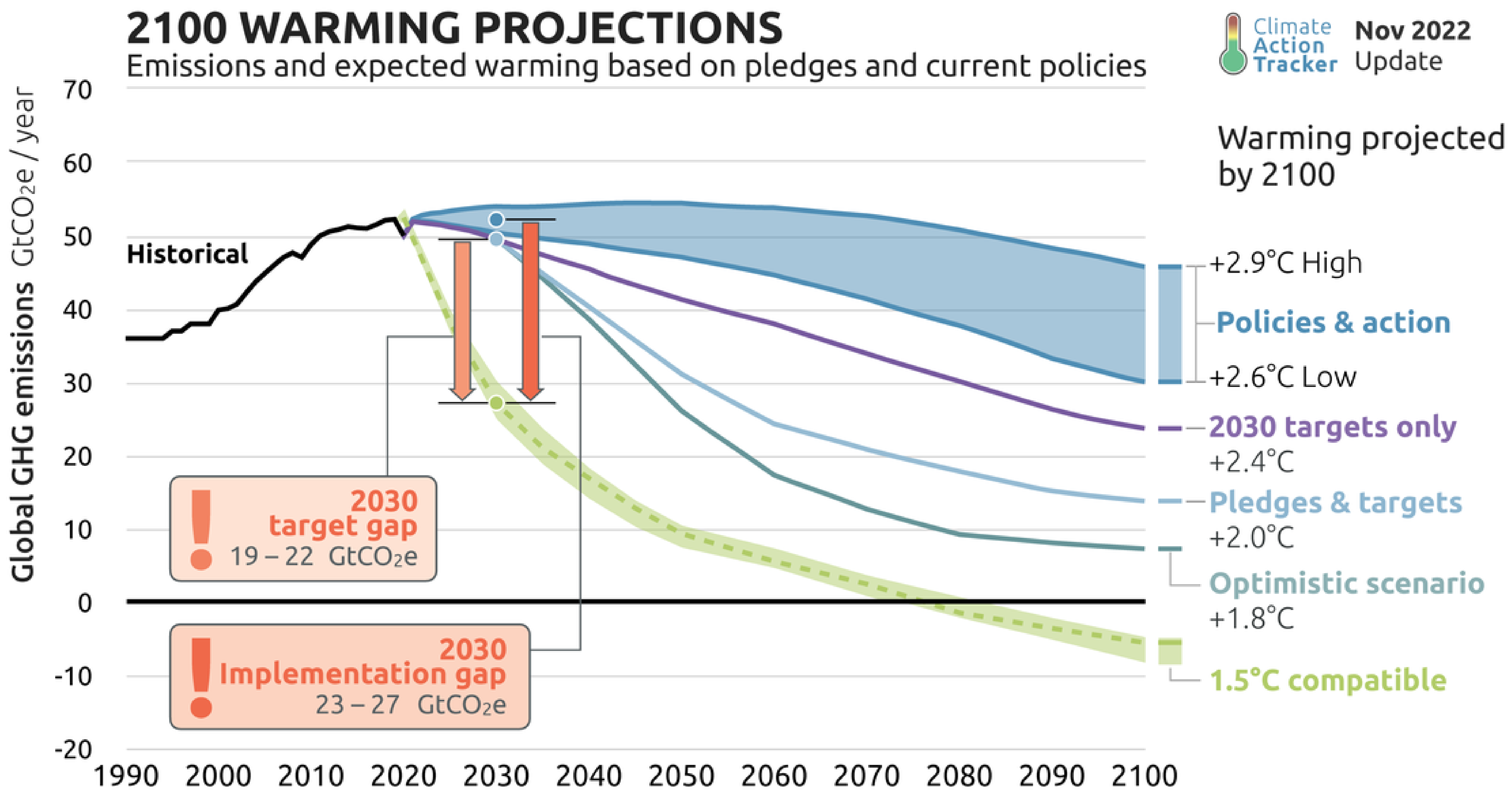
IPCC AR6, WG1 2021



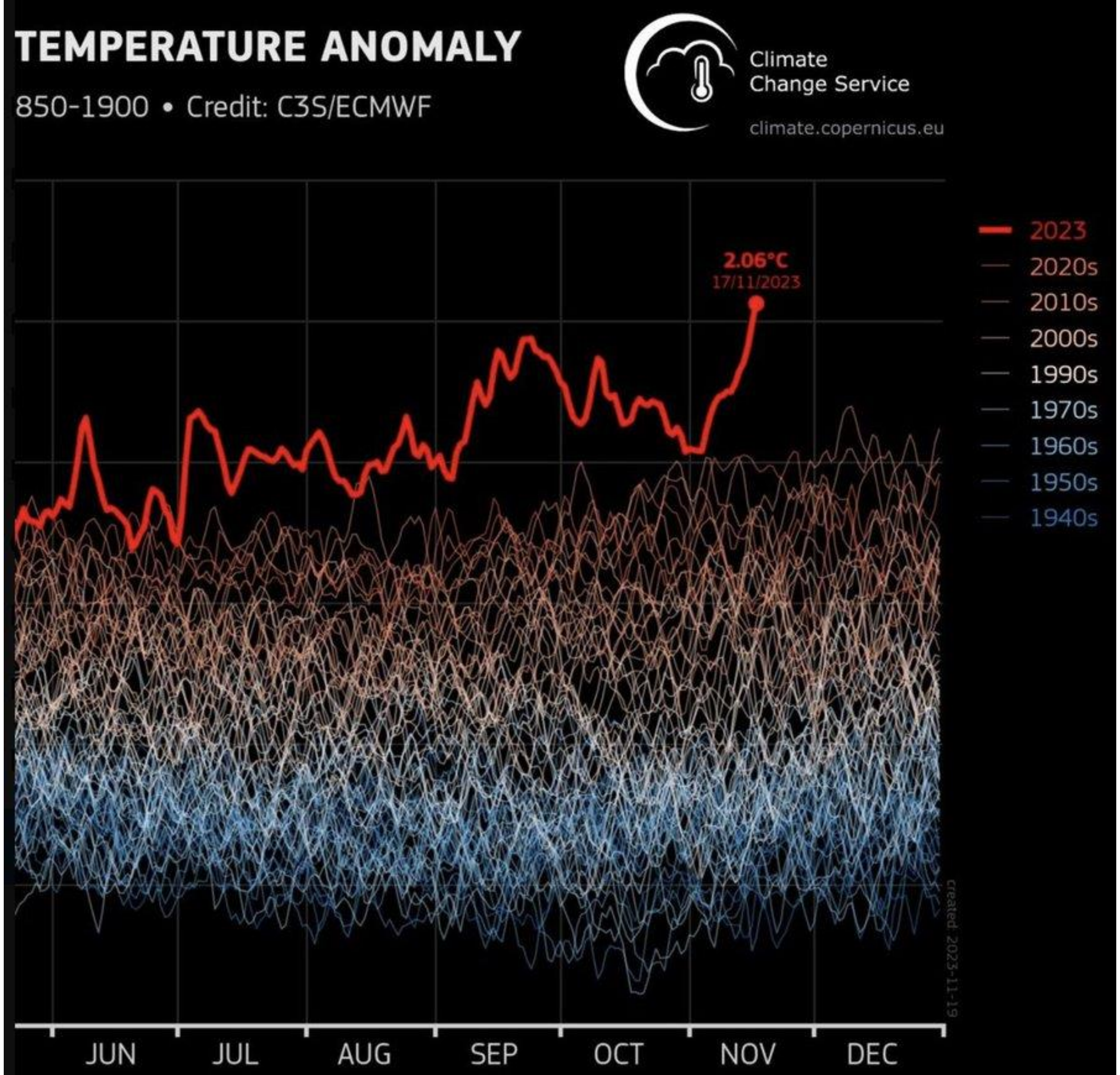
NASA, 2022



Question: What is the 30-year average annual air temperature in your city?

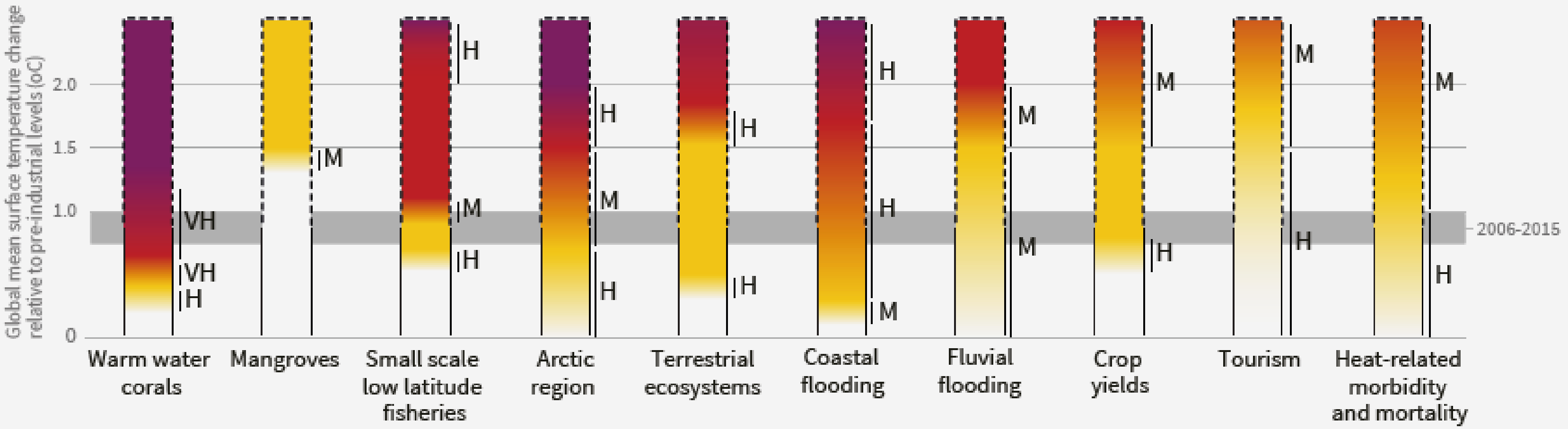


2100 WARMING PROJECTIONS
Emissions and expected warming based on pledges and current policies
Climate Action Tracker
Nov 2022 Update
Global GHG emissions GtCO2e / year
Historical
Warming projected by 2100
+2.9°C High
Policies & action
+2.6°C Low
2030 targets only
+2.4°C
Pledges & targets
+2.0°C
Optimistic scenario
+1.8°C
1.5°C compatible
2030 target gap
19 – 22 GtCO2e
2030 Implementation gap
23 – 27 GtCO2e
70
60
50
40
30
20
10
0
-10
-20
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100


TEMPERATURE ANOMALY
850-1900 • Credit: C3S/ECMWF
Climate
Change Service
climate.copernicus.eu
2023
2020s
2010s
2000s
1990s
1970s
1960s
1950s
1940s
2.06°C
17/11/2023
created 2023-11-19
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Risk is the *probability* of something happening (e.g., loss of coral reefs) while impact is the *outcome* of climate change on a sector/system.

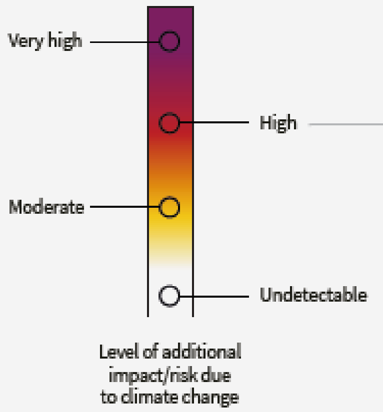
Impacts and risks for selected natural, managed and human systems



Confidence level for transition: L=Low, M=Medium, H=High and VH=Very high

Purple indicates very high risks of severe impacts/risks and the presence of significant irreversibility or the persistence of climate-related hazards, combined with limited ability to adapt due to the nature of the hazard or impacts/risks.

Yellow indicates that impacts/risks are detectable and attributable to climate change with at least medium confidence.



Red indicates severe and widespread impacts/risks.

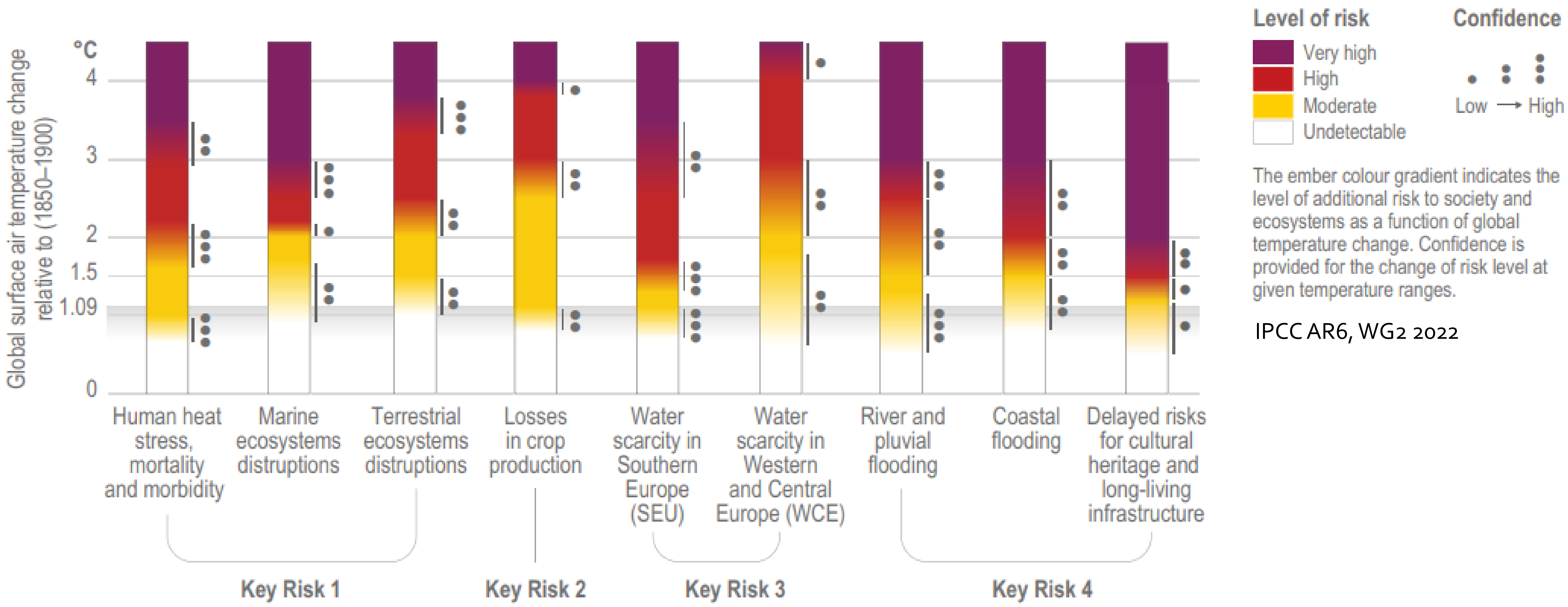
White indicates that no impacts are detectable and attributable to climate change.

The world beyond 1.5°C

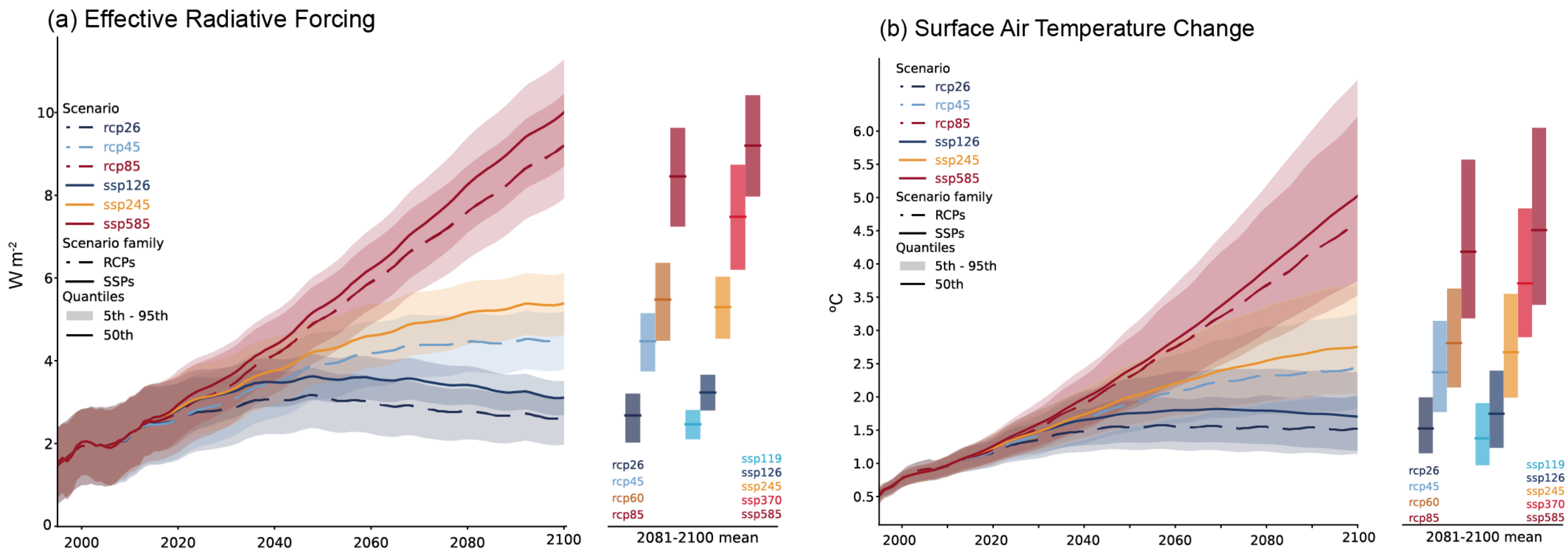
Exceeding the 1.5°C global warming limit, even if only temporarily, will lead us into a highly uncertain world. Such an overshoot will push a number of natural and human systems beyond their limits of adaptation and into possible futures about which we have limited scientific knowledge and no institutional or governance experience.

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

question: what do you see as the key risk for Europe?



IPCC AR6, WG2 2022



(a) Effective Radiative Forcing
W m-2
Scenario
rcp26
rcp45
rcp85
ssp126
ssp245
ssp585
Scenario family
RCPs
SSPs
Quantiles
5th - 95th
50th
0
2
4
6
8
10
2000
2020
2040
2060
2080
2100
rcp26
rcp45
rcp60
rcp85
ssp119
ssp126
ssp245
ssp370
ssp585
2081-2100 mean
(b) Surface Air Temperature Change
°C
Scenario
rcp26
rcp45
rcp85
ssp126
ssp245
ssp585
Scenario family
RCPs
SSPs
Quantiles
5th - 95th
50th
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
2000
2020
2040
2060
2080
2100
rcp26
rcp45
rcp60
rcp85
ssp119
ssp126
ssp245
ssp370
ssp585
2081-2100 mean

CLIMATE CHANGE
Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.' The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes.

EXPOSURE
The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected.

HAZARD
The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.

RISK
The potential for adverse consequences where something of value is at stake and where the occurrence and degree of an outcome is uncertain. In the context of the assessment of climate impacts, the term risk is often used to refer to the potential for adverse consequences of a climate-related hazard, or of adaptation or mitigation responses to such a hazard, on lives, livelihoods, health and well-being, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure. Risk results from the interaction of vulnerability (of the affected system), its exposure over time (to the hazard), as well as the (climate-related) hazard and the likelihood of its occurrence.

RISK ASSESSMENT
The qualitative and/or quantitative scientific estimation of risks.

RISK MANAGEMENT
Plans, actions, strategies or policies to reduce the likelihood and/or consequences of risks or to respond to consequences.

SENSITIVITY
The degree to which a system or species is affected, either adversely or beneficially, by climate change.

VULNERABILITY
The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

ADAPTATION
The process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities.

ADAPTIVE CAPACITY
The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.

CLIMATE
Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.

IMPACTS (CONSEQUENCES, OUTCOMES)
Impacts generally refer to effects of climate-related hazards (including extreme weather and climate events) on lives; livelihoods; health and well-being; ecosystems and species; economic, social and cultural assets; services (including ecosystem services); and infrastructure. Impacts may be referred to as consequences or outcomes, and can be adverse or beneficial.

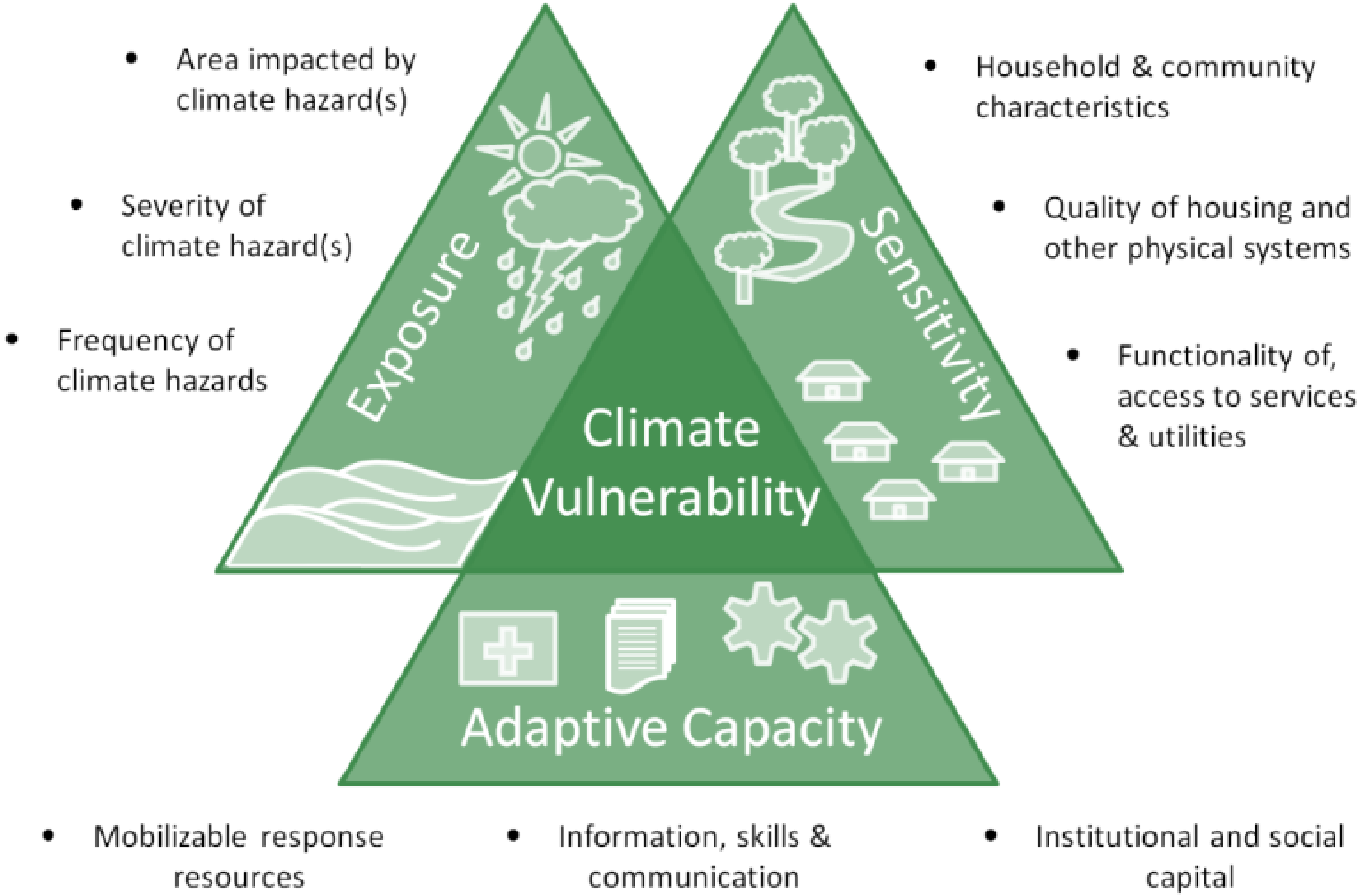
LIKELIHOOD (PROBABILITY)
The chance of a specific outcome occurring, where this might be estimated probabilistically.

MITIGATION (OF CLIMATE CHANGE)
A human intervention to reduce emissions or enhance the sinks of greenhouse gases.

RESILIENCE
The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure while also maintaining the capacity for adaptation, learning and transformation.

- **Physical Risks** are related to the physical impacts of climate change, driven by acute weather events such as floods and storms, and chronic long-term shifts such as temperature increase and sea level rise.
- **Transition Risks** are related to the transition to a lower-carbon economy, which may entail extensive policy, legal, technology and market changes.

IPCC, 2018: Annex I: Glossary; CDP CLIMATE RISK AND VULNERABILITY ASSESSMENT 2022 (resources at the end)



UN habitat

IPCC AR6

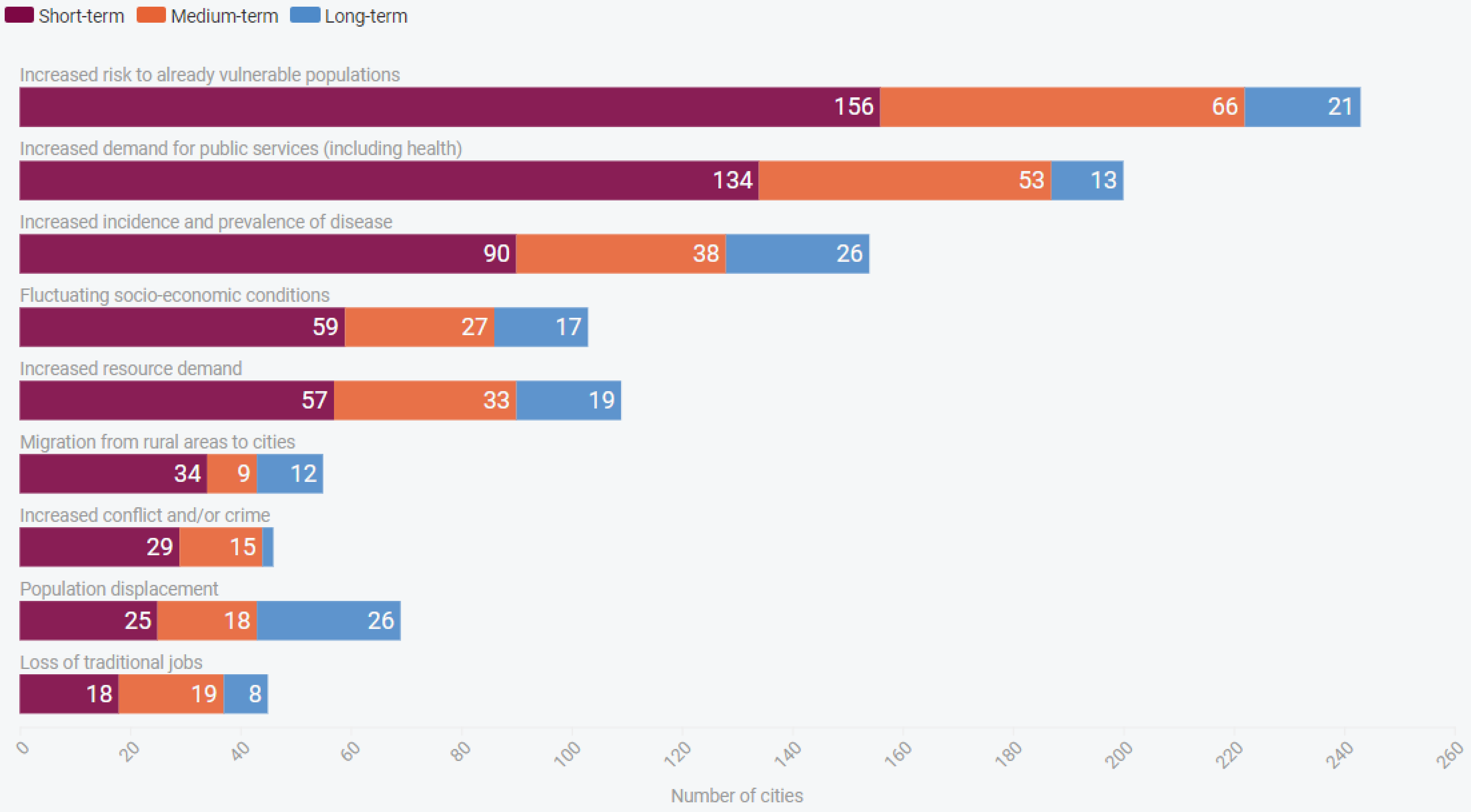
	LIVING	WORKING	MOVING
HEAT	Decreased comfort Health risks Increased energy use for cooling, decreased for heating	Reduced labour productivity Increased energy use for cooling, decreased for heating	Discomfort on public transport Rail buckling Increased energy use for cooling, decreased for heating
FLOODS	Nuisance/health risks Damage to houses Power and water failures	Reduced accessibility Economic asset damage Power and water failures	Blocked roads and rail
WATER SCARCITY	Discomfort Health and safety risks	Reduced productivity Power and water failures	Shipping constraints
WILD FIRES	Health and safety risks Damage to houses	Damage to economic assets	Transport route blockage
STORMS	Nuisance/health risks Damage to houses Power and water failures	Economic asset damage Reduced accessibility Power and water failures	Blocked roads and rail

Note: The examples are not exhaustive and they may not be relevant for all cities.

EEA: Urban adaptation to CC in Europe, 2016

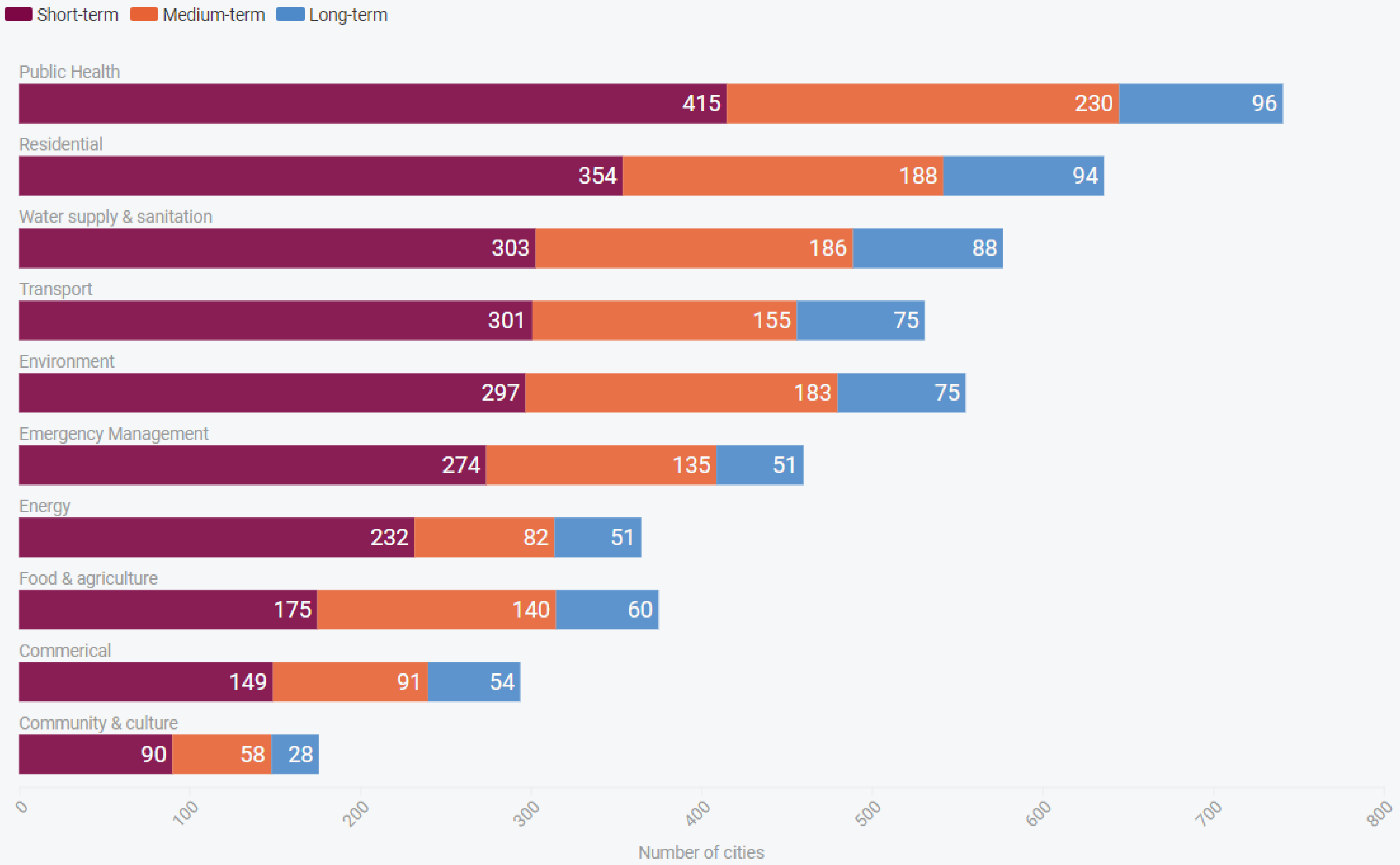
Climate change poses serious social risks, and already-vulnerable populations will be the most heavily impacted

The chart below explores the top social risks cities are identifying as a result of climate change, alongside in the time period in which they expect these risks to manifest.



Climate change is threatening vital public services, and public health services will be the most heavily impacted

The chart below explores which public services were identified by cities as most vulnerable to climate-related risks in the short, medium and long-term



Urban
Adaptation Support Tool
Covenant of Mayors
for Climate & Energy
EUROPE

https://climate-adapt.eea.europa.eu/en/knowledge/tools/urban-ast/step-2-0

- Getting started
- 1 Preparing the ground for adaptation
- 2 Assessing climate change risks and vulnerabilities
    - 2.1 Recognizing past and present climate impacts
    - 2.2 Understanding climate projections and future impacts
    - 2.3 Identifying vulnerable urban sectors
    - 2.4 Conducting risk and vulnerability assessments
    - 2.5 Understanding the role of surrounding areas in adaptation
    - 2.6 Identifying main adaptation concerns and defining objectives
    - 2.7 Assessing climate change risks and vulnerabilities: Self check
- 3 Identifying adaptation options
- 4 Assessing and selecting adaptation options
- 5 Implementing adaptation
- 6 Monitoring and evaluating adaptation

new hazards and impacts may also occur

correctly interpreting information

impact in area providing services; disrupted access to urban jobs, resources and various services

The MISSION CE CLIMATE Indicator Framework (tool) is an Excel spreadsheet with separate worksheets for Hazard Indicators, Exposure Indicators, Vulnerability Indicators and Response / Adaptive Capacities Indicators.

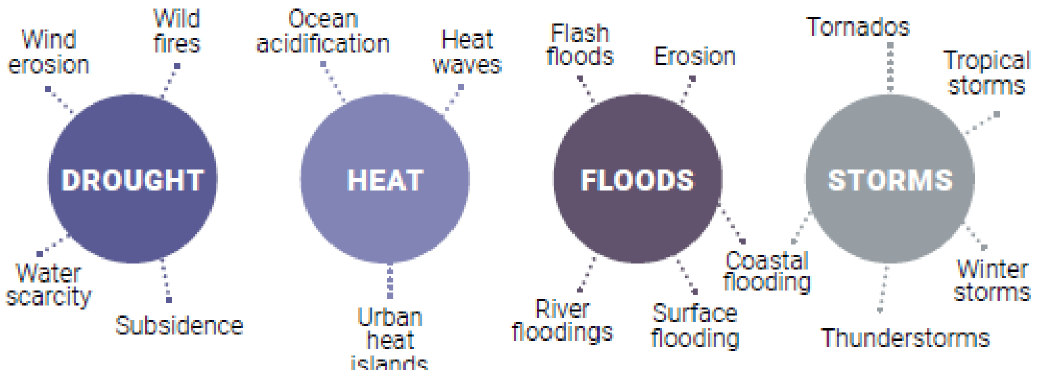
Indicator Name	Unit	Rationale	Indicator Details	Indicator description	Indicator suggested by	Risk Domain	Link	Latest year of avalilable data	Level of Data (NUTS 1/2/3, City; degree of urbanisation, city specific)	Indicator Score	Range of values	Ranking Method (e.g. EU range based or self-determined range - split into 5 classes)	Hazard Risk Score	Trend	Comment
Climate indicators to be considered as part of		Standardised climate indicators:			Urban Adaptatic	Standardised climate indicators	https://climate-adapt.eea.europa.e								AND OTHER SOURCES
HEAT															
Summer heatwave days	% change	High temperatures are probably the most urgent climate hazard for cities in terms of risks to human life. Heat affects well-being and can be lethal for elderly and persons in poor health, in particular when longer spells of hot days and warm nights (heatwaves) occur.	Projected change in the percentage of summer days classified as heatwave days between 1951-2000 and 2051-	Heatwaves were defined as three consecutive days where both the maximum and the minimum temperature exceed their respective 95th percentile	EEA	Hazard	https://sdi.eea.europa.eu/catalogue/srv/eng/catalog.search#/metadata/8e5ee71f-1136-4a07-b5fd-		e.g. city level (EU data)	e.g. MB - 40-50% (for high impact scenario)		0-20 low 20-30 medium low 30-40 medium 40-50 medium high 50 + high	Medium High	Increasing	
Apparent Temperature Hea	N°		The index gives the number of days with prolonged periods of simultaneous extreme humidity and heat	The Apparent Temperature Heatwave Days Index (Number of Days) is defined as a period of at least two consecutive days during the	Climate-ADAPT	Hazard	https://climate-adapt.eea.europa.eu/en/metadata/indicators/apparent-temperature-		NUTS 2	East Slovenia = 11.3		Range 5-18	Medium High	Decreasing	
High UTCI Days	N°		The index gives the number of days with either strong, very strong and extreme heat stress.	The Universal Thermal Climate Index (UTCI) days index is relevant to human health. A higher value indicates more High UTCI days and thus more	Climate-ADAPT	Hazard	https://climate-adapt.eea.europa.eu/en/metadata/indicators/high-utci-days		NUTS 2	East Slovenia		Range 0-80+	Medium low	Increasing	available aggregated data from 1980-2010
Number of heat wave days	N°		Change in the number of days with a maximum temperature of more than 35°C between the 1981-2010 period	This indicator shows the difference in the number of days with a maximum temperature of more than 35°C between the 1981-2010 period	European Climate Risk Typology	Hazard	https://european-crt.org/map.html								
Extreme heat waves	N°		Projected number of extreme heatwaves in near future (between 2020-2052)	Under the RCP8.5 scenario, very extreme heat waves (much stronger than either the 2003 or the 2010 heat waves) are projected to occur as often	Urban Adaptation Map Viewer	Hazard	https://eea.maps.arcgis.com/apps/MapSeries/index.html?appid=ec9a942228894562bd53310e3c3bc								
Projected change in tropica	N°		Difference in the number of days with minimum temperature more than 20°C during the night, between the 2036–2065	This indicator shows the difference in the number of nights where the minimum temperature does not drop below 20°C between the 1981-	European Climate Risk Typology	Hazard	https://european-crt.org/map.html								
Urban Heat Island (UHI) int	°C	Cities are warmer than their surroundings because buildings and tarmac store heat during the day and release it at night. In highly	Urban Heat Island Intensity	Urban Heat Island (UHI) intensity (in degrees Celsius °C) is based on cities parameters of elevation above sea level, land use, soil sealing,	Urban Adaptation Map Viewer	Hazard	https://eea.maps.arcgis.com/apps/MapSeries/index.html?appid=ec9a942228894562bd53310e3c3bc								
FLOODS															
Projected Very Heavy Precipitation Days (RCP 8.5)	Number of days with precipitation greater than	Flooding causes fatalities, injuries and stress, affects housing and infrastructure. Population groups that are	Difference between the 2036–2065 period and the 1981–2010 period for the IPCC RCP8.5	Very heavy precipitation days is a globally recognised and standardised climate indicator. This indicator shows the	European Climate Risk Typology	Standardised climate indicator	https://european-crt.org/map.html								

Suggested illustration of the indicator score					
Hazard/ Exposure / Vulnerability	Highest	Medium-high	Medium	Medium-low	Lowest
Responses /Capacities	Highest	Medium-high	Medium	Medium-low	Lowest

HAZARD ASSESSMENT

1. DETERMINE THE RELEVANT CLIMATE HAZARDS

Which climate hazards affect your city?



2. SELECT RELEVANT CLIMATE INDICATORS

What data do you need to measure each hazard?

- Climatology data (or "**primary effect**" indicators) – the physical effect of climatic events, e.g., **rainfall intensity, temperature, wind speed**, etc.
- Hazard maps (or "**secondary effect** indicators) – showing the changes to the city systems caused by the climatic event, e.g., **floods maps, erosion maps, subsidence maps, biodiversity loss**, etc.
- Sector maps (or "**tertiary effect**" indicators) – showing the changes to the human system caused by the climatic event. They are closely related to the *impacts* caused by climatic events, e.g., **land use maps, infrastructure maps, damage maps**, etc.

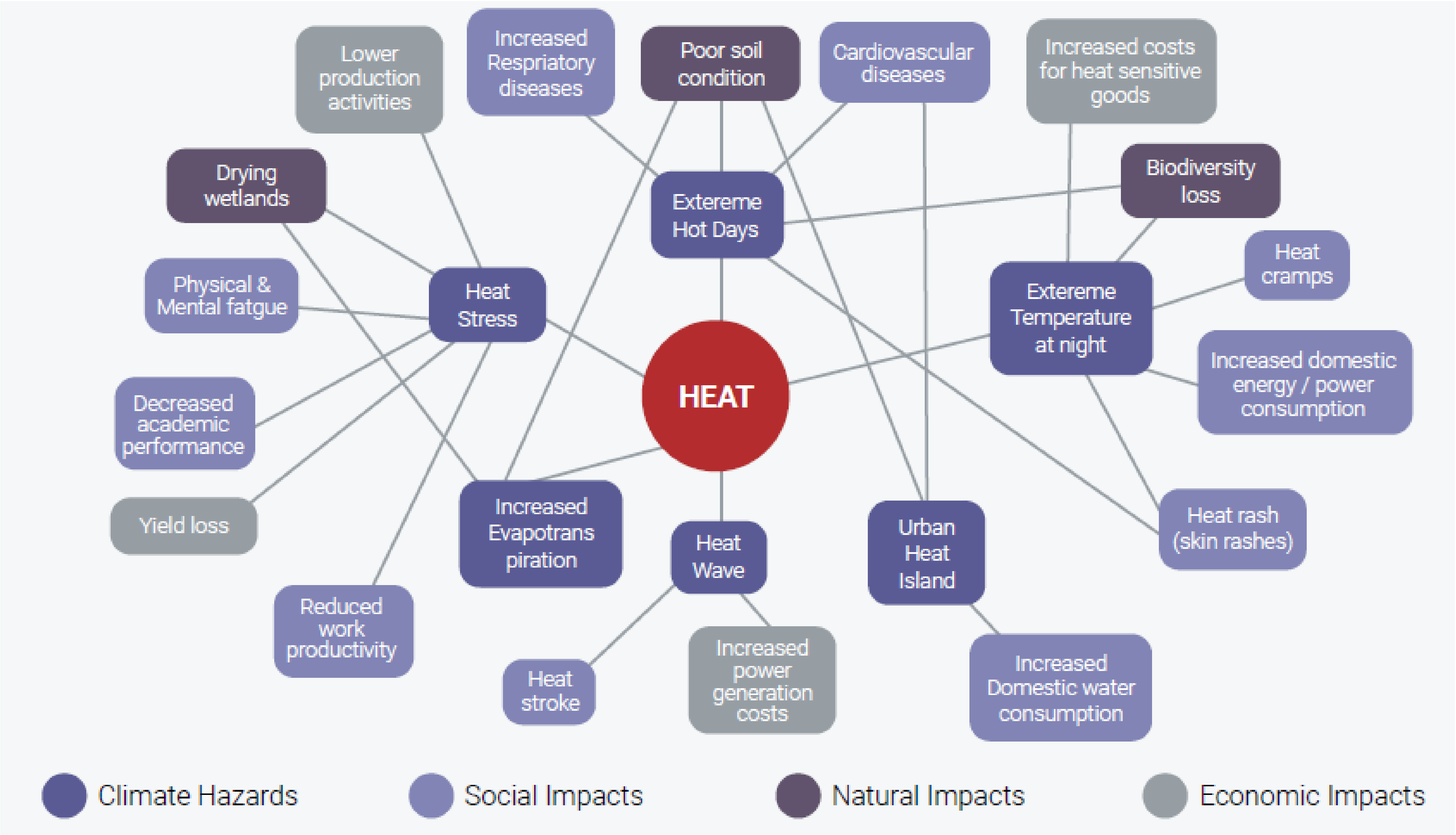
3. ANALYSE HISTORICAL TRENDS AND EVENTS

How has each hazard affected your city in the past?

4. ANALYSE FUTURE PROJECTIONS

How will each hazard affect your city in the future?

- **Climate scenarios**: These are typically defined as different future emissions pathways or warming levels, depending on actions taken to reduce global GHG emissions. The IPCC defines several possible modelled scenarios in their most recent report ranging from limiting warming to 1.5°C, in line with the Paris Agreement, to a worst-case scenario projecting warming of up to around 5°C. It is good practise to evaluate a worst-case or high emissions scenario, to understand the most extreme potential effects of a city's climate hazards.
- **Time horizon**: when modelling future climate effects, cities should select a time horizon to communicate the expected effects at a selected time point. It is best to select a time horizon aligning with the city's long-term plans, e.g., 2050.

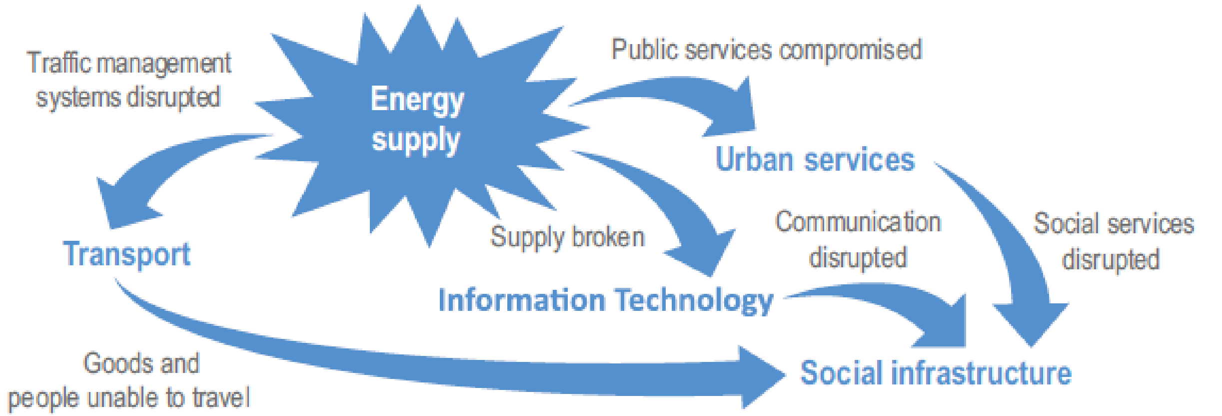


3. ASSESS IMPACTS OF THE CLIMATE HAZARDS ON EACH SECTOR

How does each hazard impact each city sector?

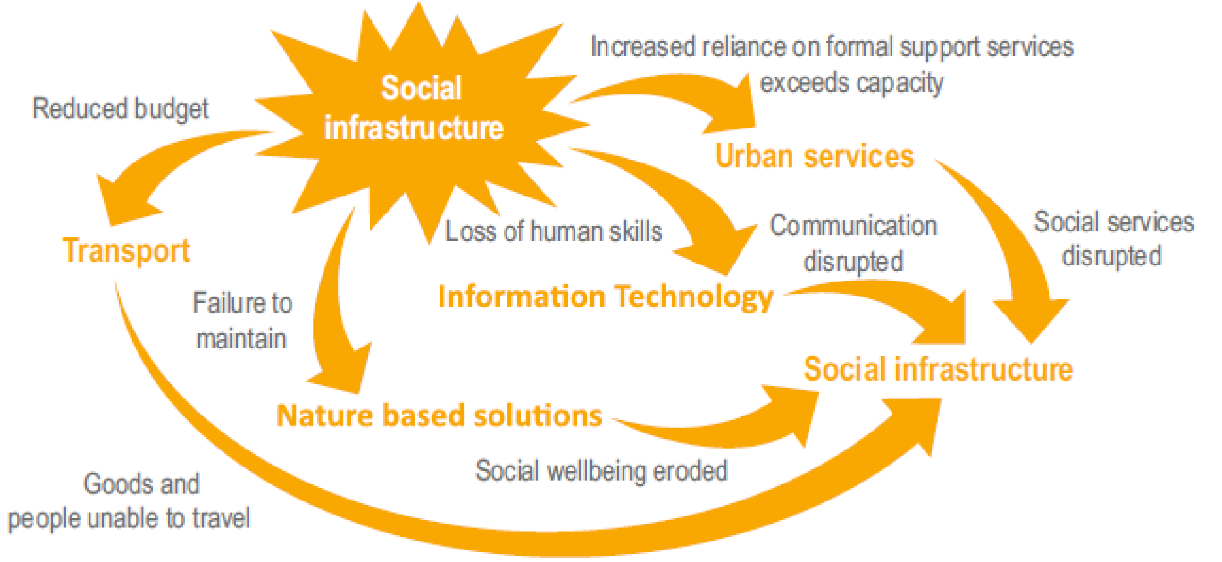
Climate Impacts Cascade Through Infrastructure

1 Rapid onset event, e.g. flood or storm surge

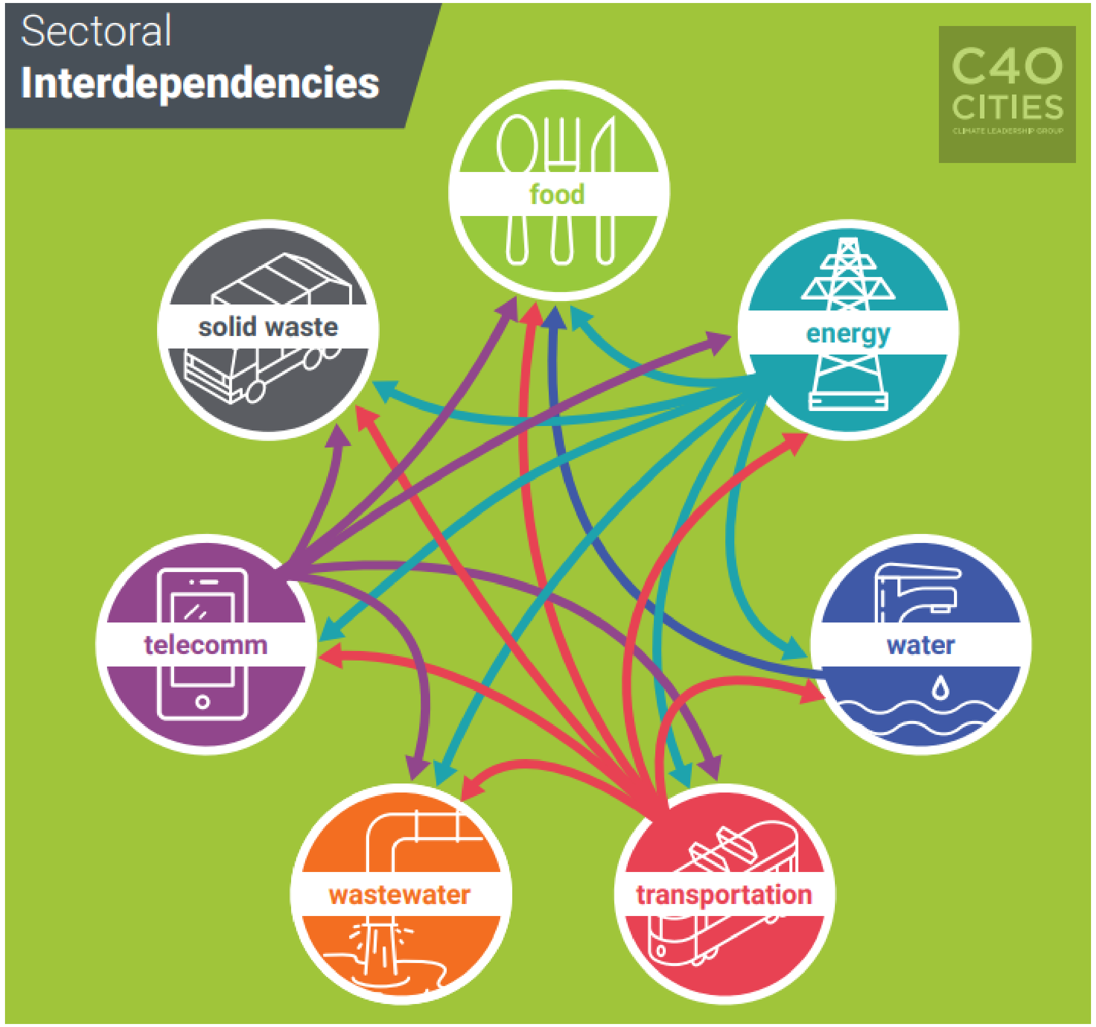


A flash flood damages energy supply, for example by flooding an electricity sub-station. This direct impact of the flood cascades rapidly to produce compound impacts on social infrastructure through compromising urban services, breaks in IT services and shutdown in traffic management.

2 Slow-onset or chronic impacts, e.g. recurrent food price shocks or everyday flooding

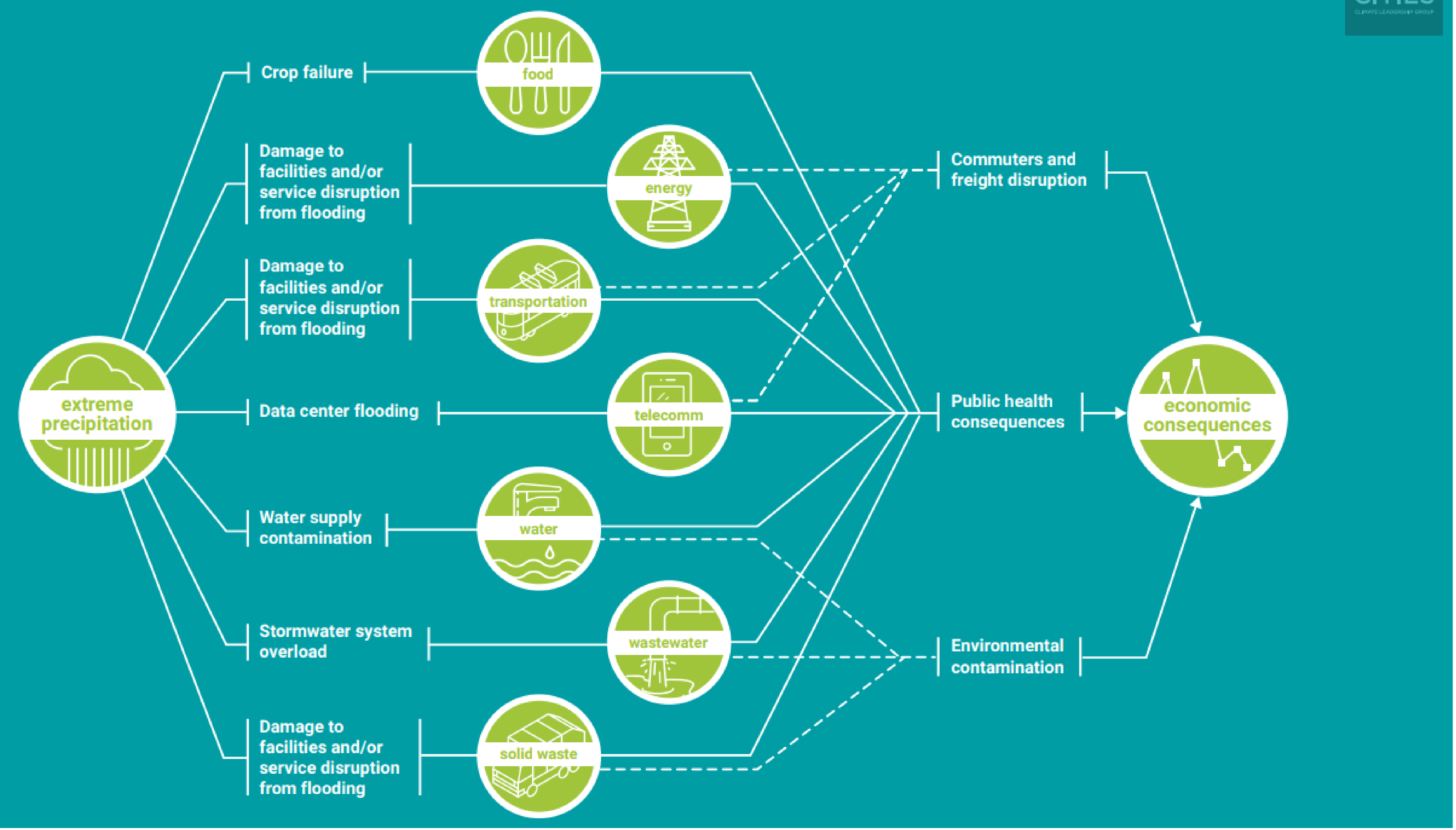


The chronic impacts of everyday flooding damage social infrastructure over time as livelihoods, local health and education services are eroded. These impacts cascade through reduced city tax income at a time when there is increased demand for urban services including public transport, out-migration of skilled workers reduce the skill base to maintain IT and nature based solutions such as public parks. These impacts in turn constrain social infrastructrue.

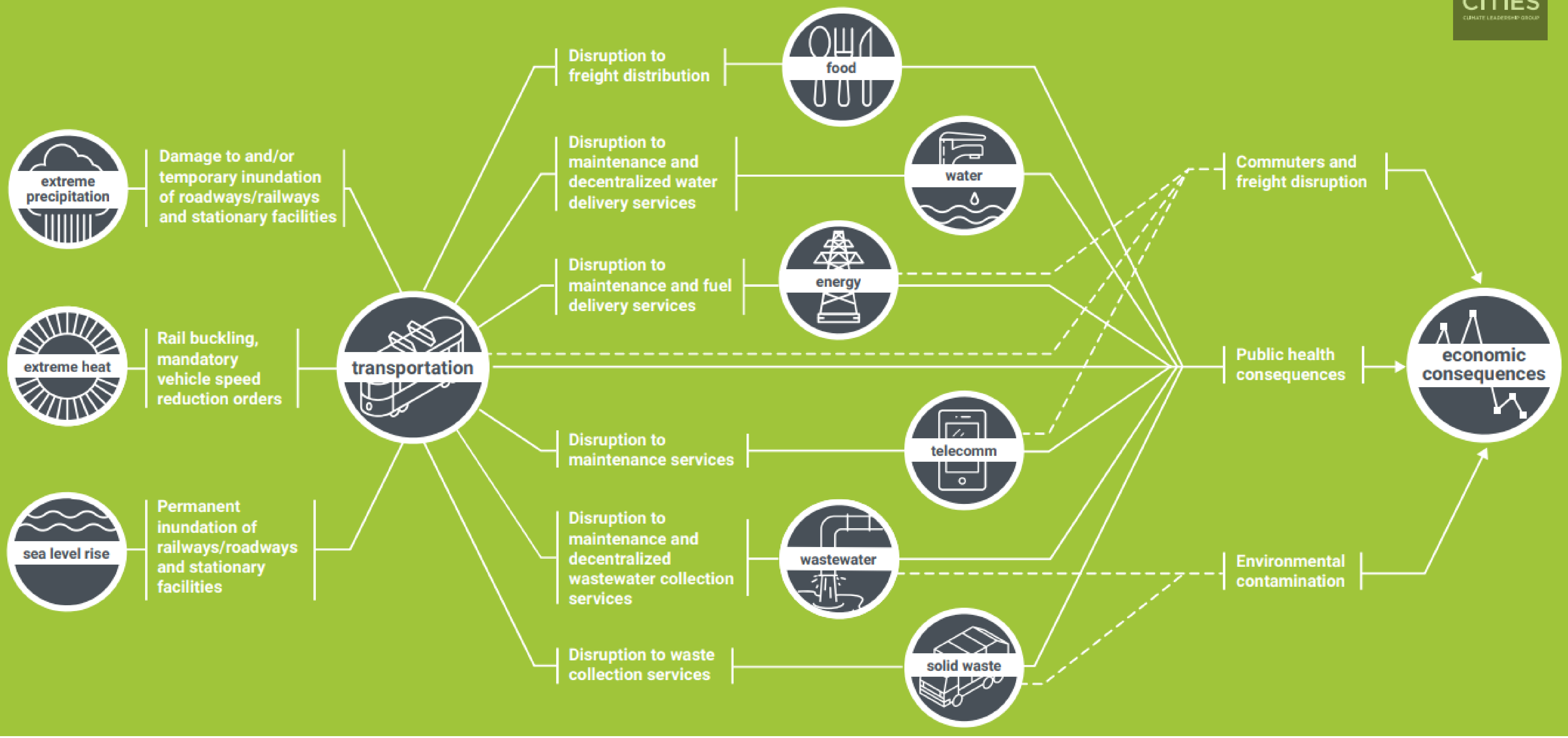


https://resourcecentre.c40.org/resources/assessing-risks-in-cities

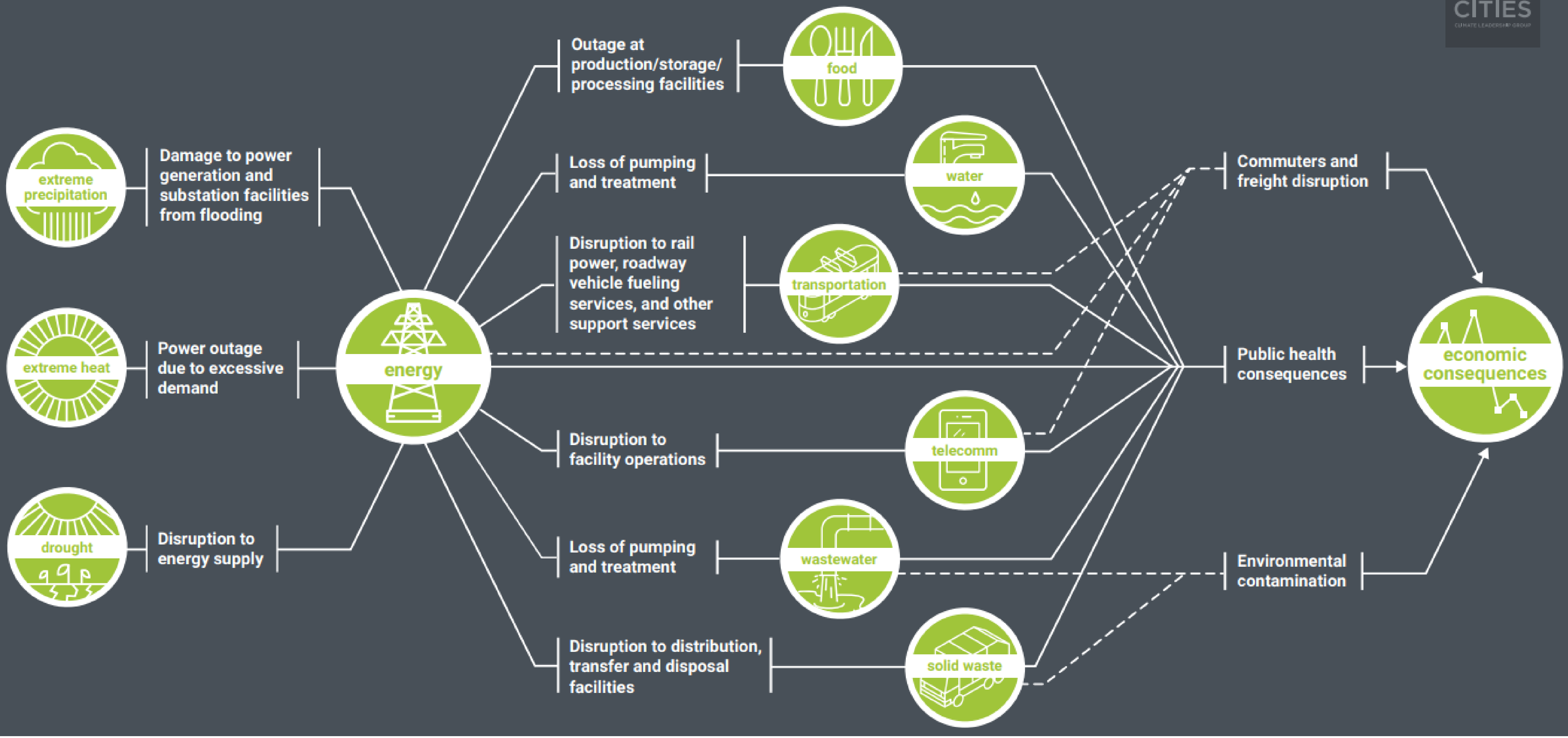
Example of a climate hazard that impacts multiple sectors: **Extreme precipitation**



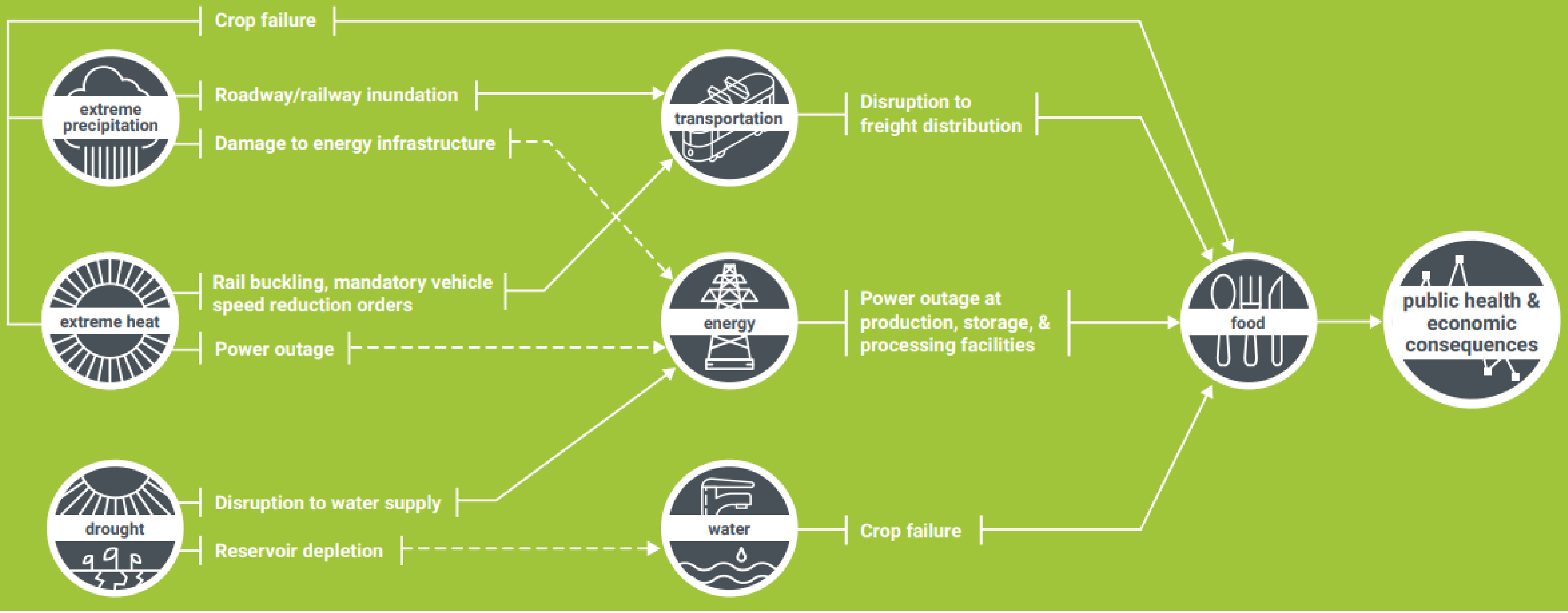
Example of a sector that impacts multiple sectors: **Transportation**

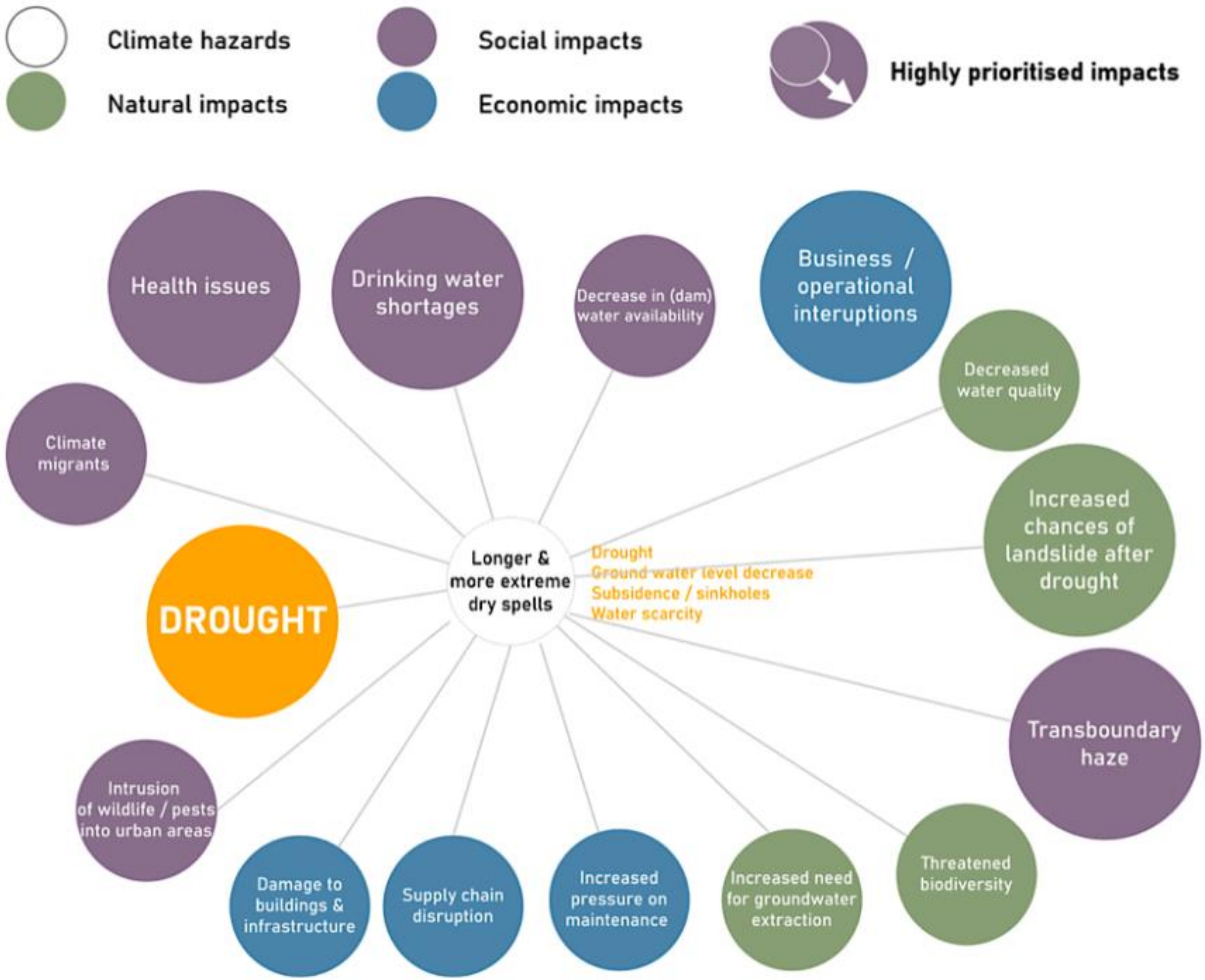


Example of a sector that impacts multiple sectors: **Energy**



Example of a sector which depends on multiple sectors: **Food**





Climate hazards
Social impacts
Highly prioritised impacts
Natural impacts
Economic impacts
Health issues
Drinking water shortages
Decrease in (dam) water availability
Business / operational interuptions
Decreased water quality
Climate migrants
Increased chances of landslide after drought
Longer & more extreme dry spells
Drought
Ground water level decrease
Subsidence / sinkholes
Water scarcity
DROUGHT
Transboundary haze
Intrusion of wildlife / pests into urban areas
Damage to buildings & infrastructure
Supply chain disruption
Increased pressure on maintenance
Increased need for groundwater extraction
Threatened biodiversity

ASSESS ADAPTIVE CAPACITY

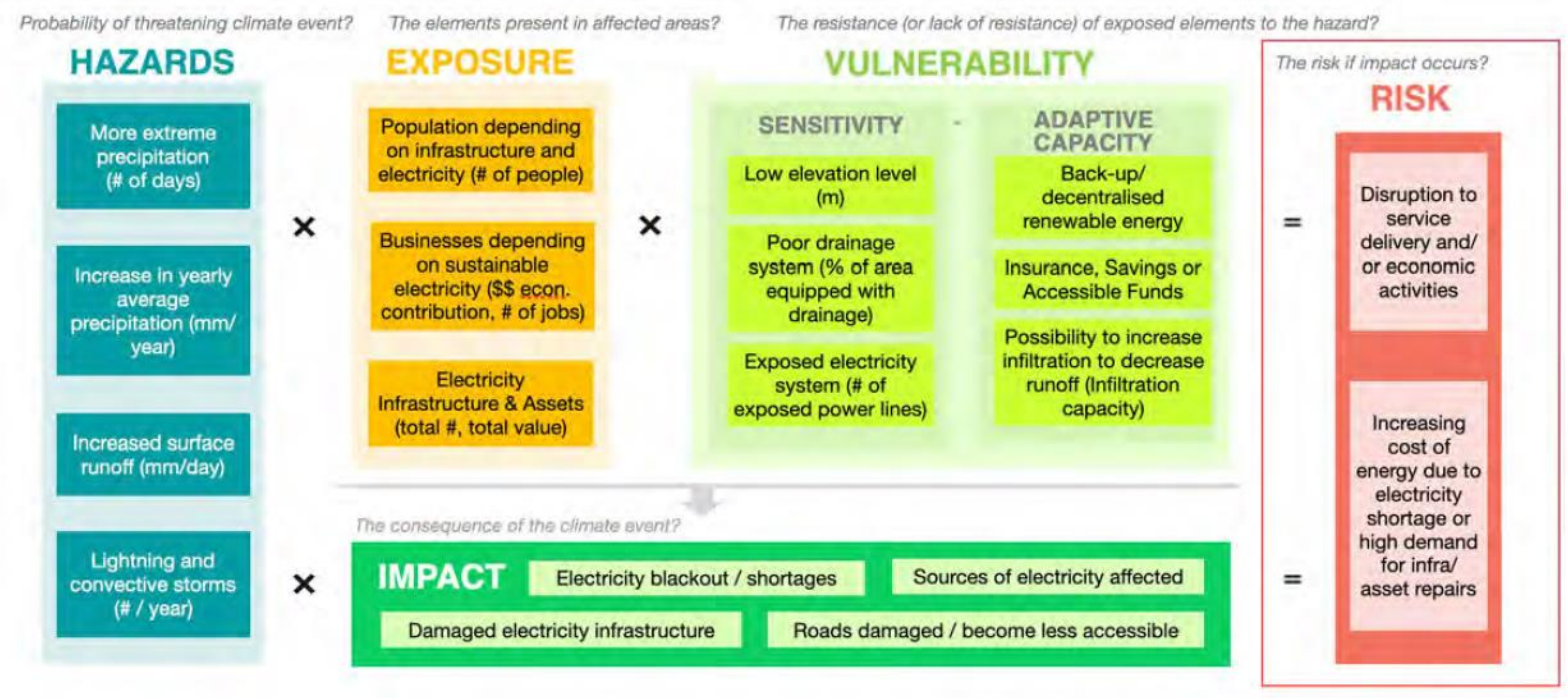
Which factors will affect your city's ability to adapt?

Identify relevant factors which will affect your city's ability to adapt to the impacts of climate change – these factors may **support** or **challenge** your city's adaptive capacity.

Examples of factors:

SOCIO-ECONOMIC	GOVERNMENTAL	PHYSICAL & ENVIRONMENTAL	SERVICES
Cost of living	Political stability	Rapid Urbanization	Acces to basic services
Housing	Political engagement	Resource availability	Access to healthcare
Poverty	Government capacity	Environmental conditions	Access to education
Inequality	Budgetary capacity	Infrastructure condition	Public health
Unemployment	Safety and security	Infrastructure maintenance	
Migration	Land use planning	Infrastructure capacity	
Economic health	Access to quality / relevant data		
Econonomic diversity	Community engagement		

EXAMPLE: Energy sector



Climate Risk Statements	Likelihood	Consequence	Risk score (Likelihood x Consequence)	Risk Status
Increased precipitation disrupts/ damages water supply infrastructure	4	4	16	High
Increased precipitation can cause water to freeze in the pipelines	4	4	16	High
Increased temperatures will lead to increased demand for water thereby posing additional stress on the supply system	3	3	9	Medium

Climate Fragility Statements	Vulnerable Areas	Urban Actors		Adaptive Capacity of the System		
		Vulnerable Actors	Potential Supporting Actor	Low	Medium	High
e.g.: Contamination of water supply due to flooding made worse by lack of alternative sources	*Ward 5*	• *Slum Dwellers* • *Resident Welfare Association* • *NGOs*	• *Private sector* • *Water Authority*	*Economic* *Ecosystem Services*	*Technology* *Governance*	*Societal*

CITY OF SOMERVILLE

Most Vulnerable Assets

Critical Assets	Sea Level Rise	Precipitation	Temperature
Amelia Earhart Dam	■		
Somerville District Court	■	■	
Cooling Center (Ward Two)	■		
Cooling Center (West Somerville)	■		
Union Square Fire Station		■	
Police Headquarters		■	
Union Square Health Center		■	
Next Wave Junior High School		■	
Full Circle High School		■	
East Somerville Community School		■	
Capuano Early Childhood Center		■	
Albert F Argenziano School		■	

Energy	Sea Level Rise	Precipitation	Temperature
Mystic Generating Station, Everett	■		
Amerigas Propane	■	■	
Mystic Substation	■	■	
Prospect Substation		■	
Bow Street Substation		■	
Washington Street Substation		■	
Linwood Street Substation		■	

Bike Paths	Sea Level Rise	Precipitation	Temperature
Alewife Greenway Path	■	■	
Mystic River Pathway	■	■	
Assembly Square Drive	■	■	■
Powderhouse Boulevard	■	■	
Cross St		■	■
Tufts St		■	■
Elm St		■	■
Willow Ave		■	■
Highland Ave		■	■
Holland St		■	■
Community Path		■	■
College Ave		■	■
Cameron Ave		■	■
Broadway		■	■
Medford St		■	■
Joy St		■	■
Dane St		■	■
Beacon St		■	■
Park St		■	■
Somerville Ave		■	■

OTAWA

Table 21. Increased Volume and Intensity of Precipitation Impacts That Require a Plan to Address Risk

Impacts	City Vulnerability	Community Vulnerability	City Risk (Average)	Community Risk (Average.)
Inland flood-related damage to road infrastructure.	Medium	Medium	Medium-High[39]	Medium-High
Inland flood-related access issues to key roadways, property and infrastructure throughout the community, leading to isolation of residents and/or challenges for emergency services.	Medium	Medium	Medium-High	Medium-High
Increased erosion of riverbanks adjacent to roads which could result in washouts and road closures.	Medium	Medium	Medium	Medium-High
Damage and contamination of private wells.	Medium	Medium	Medium	Medium-High
Flooding of parks, sports fields, and outside event spaces, resulting in park closures and loss of recreational opportunities.	Medium	Medium	Medium-High	Low
Riverine flooding related damage to trunk watermains at watercourse crossings or pump stations in the floodplain.	Medium		Medium-High	
Unmanageable volumes of stormwater on landfill sites.	High	Medium	Medium	Medium

Vulnerable Population Risk Sensitivity Chart

	Primary Climate Risks to Population								Economic Climate Risks to Population				
	Extreme Heat	Flooding	Air Quality	Vectorborne Disease	Food Insecurity	Water Quality Impacts	Waterborne Disease	Power Failure	Crop Yield Impacts	Mortality Impacts	Energy Costs	Property Crime	Violent Crime
children	3,945		3,945	3,945			3,945	3,945	3,945	3,945	3,945		
seniors	9,597	9,597	9,597	9,597	9,597			9,597	9,597	9,597	9,597	9,597	
disabled	9,726	9,726	9,726		9,726			9,726		9,726	9,726	9,726	
Low Income Individuals	13,032	13,032	13,032	13,032	13,032	13,032	13,032	13,032	13,032		13,032	13,032	13,032
Low Income Families	6,256	6,256	6,256	6,256	6,256	6,256	6,256	6,256	6,256		6,256	6,256	6,256
POC	17,738	17,738	17,738	17,738	17,738		17,738	17,738			17,738	17,738	17,738
Limited English	5,284	5,284	5,284	5,284	5,284		5,284	5,284	5,284		5,284	5,284	5,284
At Risk Workers	5,548	5,548	5,548	5,548			5,548						5,548
No Car	3,577	3,577	3,577			3,577	3,577		3,577				
Total by category	74,704	70,759	74,704	61,401	61,634	22,866	55,381	65,579	41,692	23,268	65,579	61,634	47,859
Percentage of Vuln pop	105%	99%	105%	86%	87%	32%	78%	92%	59%	33%	92%	87%	67%
Rank by Vuln	2	3	1	6	5	11	7	4	9	10	4	5	8
Percentage of Total Pop	76%	72%	76%	62%	63%	23%	56%	67%	42%	24%	67%	63%	49%

CAMBRIDGE

CRITICAL INFRASTRUCTURE

The ability of a city to function is tied to its infrastructure, much of which is out of public view, or simply goes unnoticed until it ceases to function.

Six major systems were studied in this phase of work:

- **Energy**
- **Critical Services**
- **Telecommunication**
- **Roadways & Bridges**
- **Transit**
- **Water/Stormwater**

With the climate scenarios in hand, the team conducted the vulnerability and risk assessments for each system to determine the most at-risk assets. Figure 21 presents the results of the risk assessments and how data were analyzed and compiled. The map of most at-risk infrastructure (Figure 22) highlights the degree of interconnectivity among the various assets. Cascading impacts based on dependencies on upstream systems, such as an electricity blackout leading to the loss of public transit, was incorporated into the consequence scores, influencing the overall risk scores for infrastructure.

	Asset		Heat		Flood	
			2030	2070	2030	2070
E Energy	E.1	MIT Co-generation Plant				
	E.2	North Cambridge Substation				
	E.3	Putnam Substation				
	E.4	Prospect Substation				
	E.5	Third Street Regulator Station – natural gas				
	E.6	Brookford Street Take Station – natural gas				
C Critical Services	C.1	Police Department headquarters				
	C.2	Public Health Department office				
	C.3	Professional Ambulance Services				
	C.4	Youville Hospital				
	C.5	Fire Company 2				
	C.6	Fire Department headquarters				
	C.7	Water Department building / City's Emergency Operations Center				
	C.8	Windsor Street Health Center				
TC Telecom	TC.1	City Emergency Communications Center (Police HQ)				
	TC.2	BBN Technologies data hub				
	TC.3	AT&T telephone office/long-line switch				
	TC.4	AT&T data hub/co-location center (CO-LOC)				
R Roadways & Bridges	R.1	Alewife Brook Parkway				
	R.2	Massachusetts Ave				
	R.3	Monsignor O'Brien Highway at Charlestown Ave/ Land Boulevard				
	R.4	Monsignor O'Brien Highway / McGrath Highway / Route 28				
	R.5	Fresh Pond Parkway / Route 60				
	R.6	Cambridge St Underpass				
	R.7	Broadway				
	R.8	Alewife Brook Parkway - intersections with Rt. 2 and Mass Ave/Rt. 16				
	R.9	Concord Turnpike/Route 2				
	R.10	Land Boulevard				
	R.11	Lars Anderson Bridge				
	R12	Memorial Drive				
	R.13	Longfellow Bridge				
	R.14	Eliot Bridge				
T Transit	T.1	Alewife Station (Red)				
	T.2	Lechmere Station (Green)				
	T.3	Alewife – Davis – Porter Rail Line (Red)				
	T.4	Lechmere – Science Park Rail Line (Green)				
	T.5	Central – Kendall Rail Line (Red)				
	T.6	Porter Square Subway / Commuter Rail Station (Red)				
	T.7	Central Square Station (Red)				
	T.8	Kendall Station (Red)				
	T.9	Fitchburg Commuter Rail Line				
	T.10	Porter – Harvard Rail Line (Red)				
	T.11	Harvard - Central Rail line (Red)				
W Water/Stormwater	W.1	Western Flagg (Charles, Separated)				
	W.2	New Street Pump Station				
	W.3	Fresh Pond Reservoir				
	W.4	CAM 004 (Alewife, Separated)				
	W.5	CAM 017 (Charles, Combined)				
	W.6	CAM 400 (Alewife, Separated)				
	W.7	Lechmere (Charles, Separated)				
	W.8	CAM 001 (Alewife, Combined)				
	W.9	D46 (Alewife, Separated)				

Fig. 21 **Most At-Risk Infrastructure Legend**
(Source: Kleinfelder, November 2015)

CITY OF ROCHESTER

Over the next 50 years, Rochester may experience

warmer winters and hotter summers.

more short-duration summertime droughts.

more days with temperatures above 90˚ F and longer heatwaves annually.

about 10% increase in average annual rainfall.

two to three times more frequent extreme weather events.

INFRASTRUCTURE

Vulnerabilities

- Stress on power grid due to higher cooling demand during heat waves
- Flooding of local roadways due to increased heavy rains
- Increased risk of damage to transportation infrastructure due to extreme storm events

Strengths/Opportunities

- Ongoing efforts to increase power transformers' capacity
- Good systems in place for dams during emergency overflow
- Bike/pedestrian network in good condition/ bridges have sufficient redundancies

NATURAL RESOURCES

Vulnerabilities

- Threat to tree species (maple, beech, birch) due to extreme temperatures
- Potential sediment issues in canal/river with increased heavy rains
- Increased risk of shoreline erosion along Lake Ontario and severe flash flooding due to extreme storms

Strengths/Opportunities

- Urban Forest Master Plan (completed 2012)
- Rochester has more than 3,500 acres of open space and parkland
- Majority of parks and recreational facilities are well-suited and have capacity for increased users

SOCIOECONOMIC RESOURCES

Vulnerabilities

- More frequent disruption to production/services due to extreme storm events
- Threat to safety of individuals with limited access to resources to manage impacts of extreme heat
- Individuals with language barriers or disabilities disproportionately affected by extreme storm events

Strengths/Opportunities

- Existing healthcare facilities and services have high capacity to address increase in service demands
- Redundancies and back up systems already built-in for most of the City's physical infrastructure systems
- City and RG&E deployed "Cool Sweep" program to help residents find relief from summer heat

https://european-crt.org/map.html

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

https://www.eurofound.europa.eu/data/european-quality-of-life-survey

https://commission.europa.eu/strategy-and-policy/strategic-planning/strategic-foresight/2020-strategic-foresight-report/resilience-dashboards_en

https://ec.europa.eu/eurostat/web/sdi/database

https://ec.europa.eu/eurostat/databrowser/explore/all/all_themes?lang=en&subtheme=educ.educ_outc.edat.edat1&display=list&sort=category&extractionId=HLTH_HLYE

https://ec.europa.eu/eurostat/web/cities/data/database

https://ec.europa.eu/eurostat/databrowser/explore/all/general?lang=en&subtheme=urb.urb_cgc&display=list&sort=category&extractionId=URB_CENV

https://www.eea.europa.eu/ims

https://ec.europa.eu/eurostat/cache/RCI/#?vis=nuts2.labourmarket&lang=en

https://climate-adapt.eea.europa.eu/en/metadata/indicators/river-flood

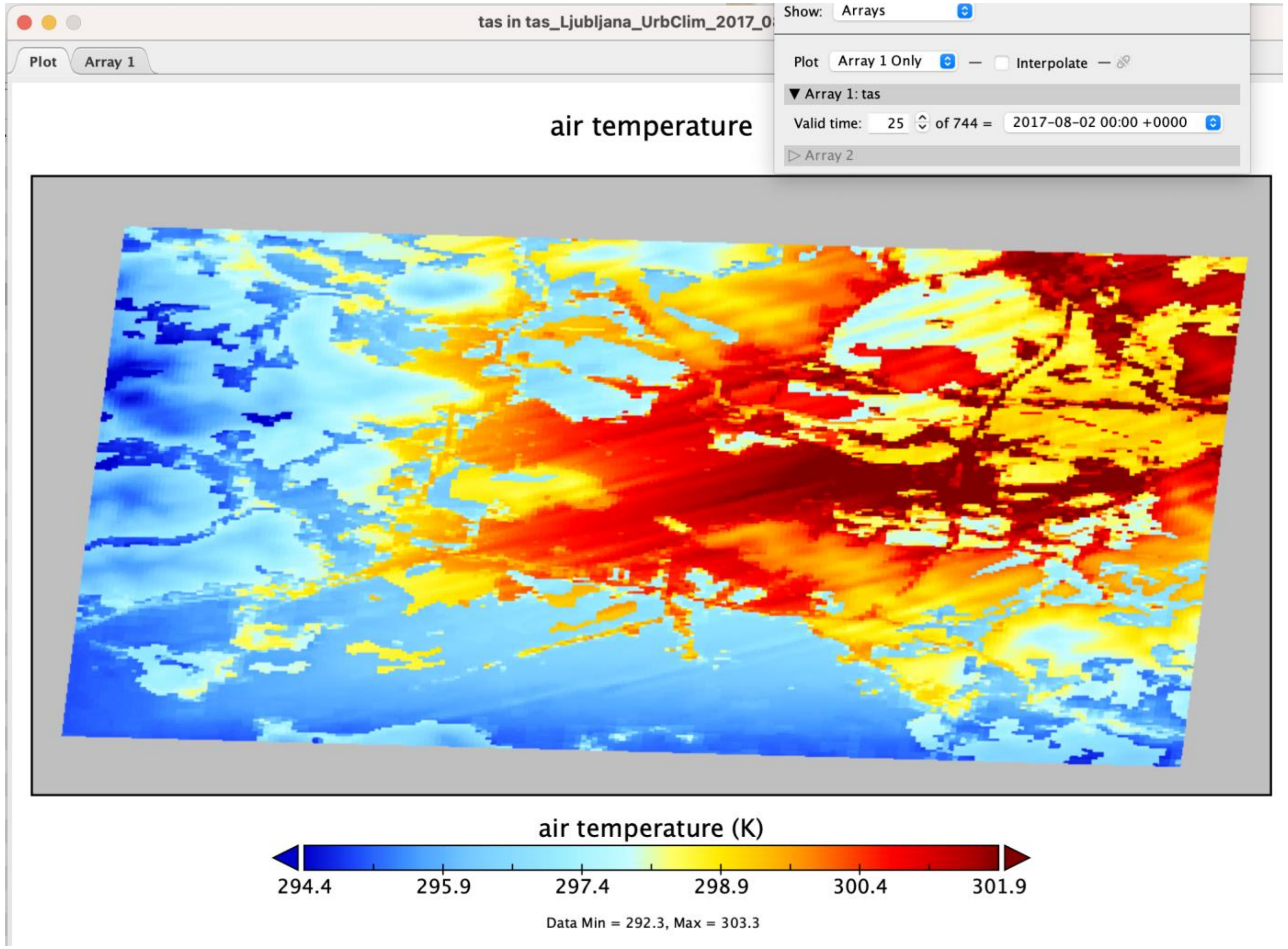
COPERNICUS climate database store:

- extreme indices (e.g. cold days, warm nights, max 5-day precipitation, heat index, WBT ...): historic data and projections for 4 SSP scenarios, yearly/monthly, global scale: https://cds.climate.copernicus.eu/cdsapp#!/dataset/sis-extreme-indices-cmip6?tab=overview
- UTCI and mean radiant temperature historic data from ERA5 from 1940 until near real time, global scale: https://cds.climate.copernicus.eu/cdsapp#!/dataset/derived-utci-historical?tab=overview
- number of hot and cold spells, Europe, 1971-2100, averaged over 30 years, RCP4.5 and RCP8.5: https://cds.climate.copernicus.eu/cdsapp#!/dataset/sis-heat-and-cold-spells?tab=overview
- Tmean, Tmin, Tmax percentiles – yearly, winter, summer for Europe, averaged over 30 years for RCP4.5 and RCP8.5: https://cds.climate.copernicus.eu/cdsapp#!/dataset/sis-temperature-statistics?tab=overview
- winter windstorm indicators for Europe from 1979 to 2021 derived from reanalysis: and financial assessment of damage for NUTS3 regions: https://cds.climate.copernicus.eu/cdsapp#!/dataset/sis-european-wind-storm-indicators?tab=overview
- hydrology-related climate impact indicators from 1970 to 2100 for Europe for RCP scenarios for river basins or 5km resolution: https://cds.climate.copernicus.eu/cdsapp#!/dataset/sis-hydrology-variables-derived-projections?tab=overview
- temperature and precipitation climate impact indicators from 1970 to 2100 for Europe, 5km resolution: T2m, highest 5-day precipitation, longest dry spells, number of dry spells, precipitation (30-years periods): https://cds.climate.copernicus.eu/cdsapp#!/dataset/sis-hydrology-meteorology-derived-projections?tab=overview
- length of season for tiger mosquitos in Europe (1986-2085), averaged over 30 years: https://cds.climate.copernicus.eu/cdsapp#!/dataset/sis-health-vector?tab=overview
- tourism indices
- sea level, wave height, storm surge

COPERNICUS

especially for some cities:

- Air temperature, relative humidity, specific humidity, wind speed for 100 European cities (2008-2017), spacial resolution 100 m, downscaled ERA5 with urban climate model for simulating urban heat island effect: https://cds.climate.copernicus.eu/cdsapp#!/dataset/sis-urban-climate-cities?tab=overview



- Extreme precipitation risk indicators from 1950 to 2019 for Europe in high resolution (2 km) for 20 cities: e.g. max 1/5-day precipitation, consecutive wet days, precipitation for some percentiles/return periods, total precipitation: https://cds.climate.copernicus.eu/cdsapp#!/dataset/sis-european-risk-extreme-precipitation-indicators?tab=overview

- Flood risk indicators for European cities from 1989 to 2018 for 20 cities; expected damage (eur/m^2), return periods: https://cds.climate.copernicus.eu/cdsapp#!/dataset/sis-european-risk-flood-indicators?tab=overview

EEA

European overview: https://experience.arcgis.com/experience/5f6596de6c4445a58aec956532b9813d/page/The-European-overview/

Evidence on climate and health: https://climate-adapt.eea.europa.eu/en/observatory

Who benefits from nature in cities: https://www.eea.europa.eu/publications/who-benefits-from-nature-in