REACHOUT
shaping climate resilient cities

D3.6: Guidelines for climate service tools

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D3.6 Guidelines for climate service tools

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1 Introduction

The REACHOUT project is developing a Triple-A Toolkit to support the uptake of climate services for climate resilience and urban adaptation in Europe (see Figure 1). To this end, a range of tools and services are being iteratively updated and tested through co-creation activities in Cross Hub Development Teams (See D3.1). This report (D3.5) is the first in a series, providing an update on the REACHOUT tools as they currently stand after the first year of development. This document will be used as the basis for an online, user-friendly overview of the tools and their main features. Following the second and third production cycles, their descriptions will be updated in the upcoming deliverables D3.6 and D3.7.

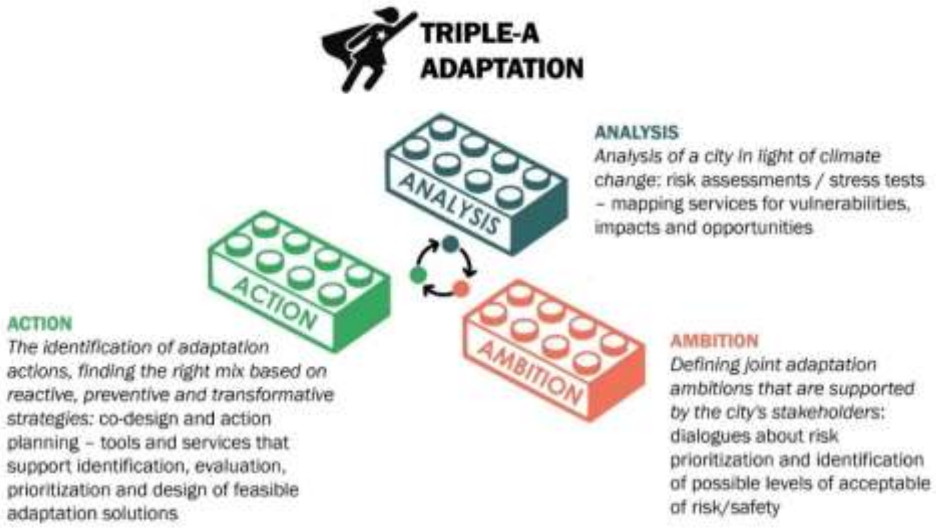


Figure 1. REACHOUT methodological framework

In the first part of the tool descriptions, we summarise general information about the REACHOUT tools including their primary purposes and benefits. The information will be of interest to city representatives, local consultants and service providers, and non-technical municipal staff or in a single case also real estate investors..

The tools and services are classified according to the pillars of the Triple-A approach: Analysis, Ambition, Action. We provide an insight into how City Hubs have implemented the tools thus far and the ways in which they might be combined with other REACHOUT tools. A user-friendly scale is used to indicate whether the overall level of complexity is 'high', 'medium' or 'low'. The climate service tools are differentiated by tools which are interesting for city representatives and tools which support decisions of the financial sector.

For the more technical reader, more detailed information helps to understand precisely which data, software programming and analytical skills are necessary to set-up and run the tools. It also contains the methodology underpinning the tool as well as key contact persons who can provide support for those interested in exploring the tool further. These sub-categories are also evaluated for their level of complexity using a 'high', 'medium', 'low' scale as before. Following the individual tool descriptions, readers are able to compare differences between the tools by referring to Table 2.

In the final section of the report, an overview of the tools according to their feasibility to use by cities is included. It used three levels of feasibility: Level 1 refers to tools which are ready to use, level 2 are tools which need some kind of customization.

2 Overview of tools

Before we turn to the individual tool descriptions, we provide an overview of all the tools and their current City Hub users as well as how these relate to the Triple-A approach in Table 1. We see that all, bar one, are used for the Analysis component. Ambition is somewhat underrepresented, but this is not surprising given that in the initial concept, it was foreseen that tools focusing on Ambition would not emerge until the second development phase. What is interesting however is that around half of the tools useful for Analysis are also relevant for determining Action, indicating an interesting potential symbiosis between structure and features of tools in these categories.

Table 1 Overview REACHOUT tools within first production cycle

Tool name	**Tool developer**	**Cities involved**	**Triple-A**		
			Analysis	Ambition	Action
Pluvial flood hazard and risk assessment in urban areas (C3S)	CMCC	Milan, Athens, Gdynia	x		x
Assessment of Risk management capabilities	CMCC	Milan	x	x	x
Climate Resilient City Tool (CRCTool)	Deltares	Lillestrom, Gdynia, Athens			x
FloodAdapt tool (Formerly known as Community Flood Resilience Support System CFRSS)	Deltares	Cork	x	x	x
Crowdsource module for climate hazard mapping	CAS	Cork	x		(x)
Climate impact diagrams	CAS	Logroño	x		
Social Vulnerability Tool	UCC	Cork, Milan, Athens, Logroño, Gdynia	x	x	x
Thermal Assessment Tool	Tecnalia	Logroño, Milan, Athens Cork and Gydnia	x		
Climate stories	NGI / CAS	All cities	x	x	x
Adaptation pathway generator tool	Deltares	Cork			x
The Adaptation Pyramid	CAS				x
Climate Resilient Development Pathways (CRDPs)	Deltares	Cork			x
Theory of change (ToC)	Tecnalia			x	x
ARCH RPVT: Resilience Pathway Visualisation Tool	Tecnalia				x

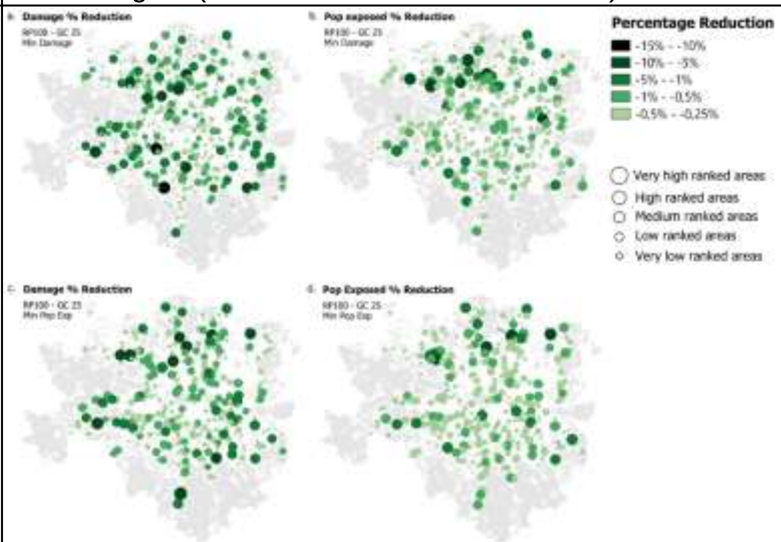
Dynamic Integrated Flood Insurance (DIFI) model	VU-IVM	Amsterdam	x		x
Real Estate Asset Climate Testing (REACT) tool	VU-IVM	Amsterdam	x		x

3 Tool descriptions

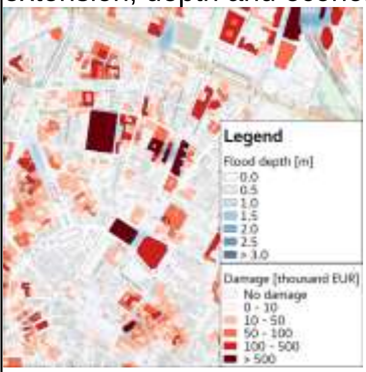
In this section we provide the details of the REACHOUT tools. Each tool is described in an overview, followed by guidance on how to use it. The tool descriptions will be used to feed into the project website to present the REACHOUT toolkit. The tool descriptions will be updated as the project develops.

3.1 Climate service tools for resilient urban areas

3.1.1 Pluvial hazard & risk assessment and adaptation

Overview	
Name of tool	Pluvial hazard & risk assessment and adaptation
Tool description (overview)	Tool designed to help local authorities to explore pluvial hazard & risk from extreme convective precipitation events and subsequent flooding due to surface rainwater accumulation which the existing urban drainage system is unable to absorb. The tool delineates the areas prone to flooding under different rainfall intensities and persistence and estimates the damage to physical assets such as buildings' structures and content. The tool is amendable to inform adaptation measures such as green urban regeneration and natural water retention measures by means of green roofs and green urban areas. The application of the tool is amendable to help users to identify existing green urban infrastructures and identify areas suitable to extend them, while controlling for the potential to reduce flood damage or share of affected population. The tool is meant for urban planners, local citizen action groups, civil society organizations, businesses and risk managers (insurers and insurance brokers).
Main graphic	 Source: Staccione et al (under review)

Benefits of using the tool	The tool enables a better appreciation of pluvial hazards and risks and empowers the users to design solutions to boost local resilience. The benefits vary across the user groups, for example urban and regional authorities gain insights into climate risks as an input to climate adaptation and disaster risk reduction strategies; businesses draw insights about how their exposure to physical climate risks and local action groups obtain insights about how the neighborhood green regeneration strategies contribute to reducing the risks. The results of the tool contribute to building a knowledge base of climate related impacts & risks.
Complementarity	The tool is complementary to other climate-related urban hazard & risk assessment services (e.g., Thermal assessment tool), serve as an input for other services such as dynamic integrated flood insurance or community flood resilience support system model and help to identify tailormade adaptation & DRR solutions.
Complexity	The complexity is variable and depends on the extent to which the users frame the analysis. It is **low** if the users access the service from a dedicated platform which allows to run the models and assess performance of some risk mitigation solutions. It is **medium to high** if the users prefer to run the underpinning open source models and control the implementation of the green regeneration strategies and green infrastructure design. *Overall level of complexity: Level 2 (customized approach)*
User stories & hub experiences	MILAN city hub has implemented the full application of the tool along with the extension to analyze the green infrastructure network. Other cities such as Athens, Gdynia and Logrono are preparing for the application of the tool.
[Examples – case studies]	Manuscript focusing on Milan submitted and under review
Guidance	
Triple-A Toolkit	The tool can be used in the following Triple-A phases: **Analysis phase:** Pluvial hazard & risk assessment – impact in terms of damage and population affected **Action phase:** Identification, evaluation, and prioritization of adaptation measures – green regeneration, nature-based solutions and urban green infrastructures (spatial connectivity)
Inputs needed	• local observational records – precipitation hourly and sub hourly data (in alternative Copernicus Climate change service – ERA5 reanalysis) • high resolution digital elevation model (ideally LIDAR), • high resolution urban green areas and impervious sur-face (optional, obtainable form Copernicus land monitoring service) *Difficulty level of inputs needed: Low – Medium difficulty*
Methodology	**First**, hourly or subhourly rainfall intensities and likelihoods are estimated from the local observational records or downscaled ERA5 reanalysis data.

	Second, using the rainfall intensity as input for the hydrostatic inundation model Safer-RAIN [1] makes it possible to delineate flood prone areas and depth of accumulated flood water for each probabilistic scenario (equivalent to return period of 5, 10, 25, 50 and 100 years). **Third**, using the hazard delineation, expected damage to physical structures is estimated using conventional and country/region specific stage-damage model and high-resolution population grid. Expected annual damage and population affected are estimated by aggregating impacts over modelled intensities/likelihoods. Building footprints are obtained from Open Streetmap and building classes are identified by using land cover data. **Fourth**, using high resolution urban green spaces as input for spatial morphological pattern analysis [2], the green infrastructure network is identified and analysed **Fifth,** building upon various scenarios of urban green regeneration such as green building conversion or extending green spaces, the performance of risk reduction measures is determined by re-running the hazard & risk model with altered inputs. *Difficulty level of use of approach: High difficulty (requires technical knowledge & expertise to run the open-source models)*
Outputs	**Maps show:** areas prone to pluvial hazard & risk, e.g., flood extension, depth and economic damage (see figure below – source [3]  *Figure 2: Estimated direct tangible damages per thousand EUR for an extreme rainfall event.* Source: [3] - areas suitable for green urban regeneration – based on the specific urban policy objectives **Tables and figures containing** annual expected damage and population affected, performance of green regeneration scenarios *Difficulty level of preparing the outputs: high difficulty*
Contacts	Jaroslav Mysiak, Jeremy Pal, Andrea Staccione Euro-Mediterranean Centre on Climate Change Risk Assessment and Adaptation Strategies division
References	[1] Mediero, L., Soriano, E., Oria, P., Bagli, S., Castellarin, A., Garrote, L., Mazzoli, P., Mysiak, J., Pasetti, S., Persiano, S., Santillán, D., Schröter, K., 2022. Pluvial flooding: High-resolution stochastic hazard mapping in urban areas by using fast-processing DEM-based

	algorithms. J. Hydrol. 608, 127649. https://doi.org/https://doi.org/10.1016/j.jhydrol.2022.127649 [2] Staccione, A., Candiago, S., Mysiak, J., 2022. Mapping a Green Infrastructure Network: a framework for spatial connectivity applied in Northern Italy. Environ. Sci. Policy 131, 57–67. https://doi.org/https://doi.org/10.1016/j.envsci.2022.01.017 [3] Essenfelder, A.H., Bagli, S., Mysiak, J., Pal, J.S., Mercogliano, P., Reder, A., Rianna, G., Mazzoli, P., Broccoli, D., Luzzi, V., 2022. Probabilistic Assessment of Pluvial Flood Risk across 20 European Cities: A Demonstrator of the Copernicus Disaster Risk Reduction Service for Pluvial Flood Risk in Urban Areas. Water Econ. Policy. https://doi.org/10.1142/S2382624X22400070 *Links to data sources needed as inputs:* - SaferPlaces: Global Platform AI-based Digital Twin Solution for Flood Risk Intelligence - Copernicus Pluvial Flood Risk Assessment in Urban Areas

3.1.2 Assessment of Risk management capabilities

Overview	
Name of tool	Assessment of Risk management capabilities
Tool description (overview)	This tool is used to guide review and/or self-assessment of risk management capabilities. Originally developed for the purpose of the country peer review under the Union Civil Protection Mechanism and adapted to different scales such as regional and local ones, the tool can assist the authorities in assessing where they stand with adaptation & disaster risk reduction and identifying major gaps or opportunities for improvement. The tool addresses all climate-related hazards & risk or a selection of thereof and is useful to assess progress made in risk governance, planning, coping capacity and recovery from climate related shocks. The tool is meant for local to national authorities, action groups, civil society organizations or other organized groups contributing to climate adaptation & disaster risk reduction strategies and plans.
Main graphic	 Source: [1]
Benefits of using the tool	Within the city hub context, this tool can be applied and used as a part of collaborative inclusive assessment of initial conditions or progress made on adaptation in urban context. The tool stimulates shared learning and knowledge sharing, awareness building and extensive dialogs/consultations
Complementarity	The tool is complementary to all other REACHOUT tools and can be applied to any of them.

Complexity	Application of the tool requires extensive knowledge of urban planning instruments, policy priorities and capabilities. Overall level of complexity: Level 1 (Ready-to-use light approach)
Link to tool webpage	NA
User stories & hub experiences	In Milan, this framework was applied to investigate the local cross-sectoral processes of identifying, analysing and evaluating the risk of the most relevant climate-related hazards insisting on the municipal territory, as well as to identify if and how this process is mainstreamed in existing disaster risk reduction and climate adaptation strategies and plans. The results for Milan can be downloaded here. It is currently being applied to a wildfire risk review in Greece. Additionally, the tool has been tested in 10 Italian cities. Its application in six major Italian cities is available here.
[Examples – case studies]	Application in six major Italian cities, other link (CMCC)
Guidance	
Triple-A Toolkit	The tool can be used in the following Triple-A phases: **Analysis phase:** - assessment of adaptation & disaster risk reduction (DRR) capabilities **Ambition phase:** - collective review of progress made and monitoring of achievements on climate adaptation and disaster risk management **Action phase:** - identification of gaps and opportunities for improvement of climate adaptation & disaster risk reduction strategies and plans
Inputs needed	• urban policies & regulation, objectives of the urban adaptation & regeneration, • policy implementation reports, • existing risk assessments, • any other assessments of potential risks & opportunities of accelerated climate change adaptation *Difficulty level of inputs needed: Low – Medium difficulty*
Methodology	The analytical framework is a technical guidance for a peer review. Peer reviews and self-assessments are well established instruments of policy analysis. They are widely used at different governance levels – from national to local – and for many different policy domains (e.g., environmental protection, civil protection capabilities, etc). ISO standard 22392:2020 embraced Guidelines for conducting peer reviews of community resilience. The ultimate aim of the peer reviews is to foster systematic assessments of performance and identification of best

	practices and gaps, in a transparent and inclusive (whole-of-society) way. Peer reviews foster cooperation and exchange of good practices, promote mutual learning, and contribute to an integrated approach to climate adaptation & disaster risk management. The analytical framework guides the fact-finding desk and in-field visits, it needs to ensure that all aspects of risk management are addressed during an inclusive stakeholder consultation process. The framework also needs to be flexible and adaptable to specific focus and context for which peer review is requested. *Difficulty level of use of approach: Low – medium difficulty*
Outputs	Comprehensive review report, including identified gaps and opportunities for improvement *Difficulty level of preparing the outputs: Low-medium difficulty*
Contacts	Veronica Casartelli, Euro-Mediterranean Centre on Climate Change, Risk Assessment and adaptation strategies division
References	UCPM Peer review program website Analytical framework (CMCC) Procedural guidance (CMCC) [1] Mysiak, J., Casartelli, V., Torresan, S. (2021). Union Civil Protection Mechanism - Peer Review Programme for disaster risk management: Assessment Framework. https://civil-protection-humanitarian-aid.ec.europa.eu/system/files/2022-01/peer_review_-_assessment_framework_sep_2021.pdf See also UCPM Peer review program (https://civil-protection-humanitarian-aid.ec.europa.eu/what/civil-protection/peer-review-programme_en)

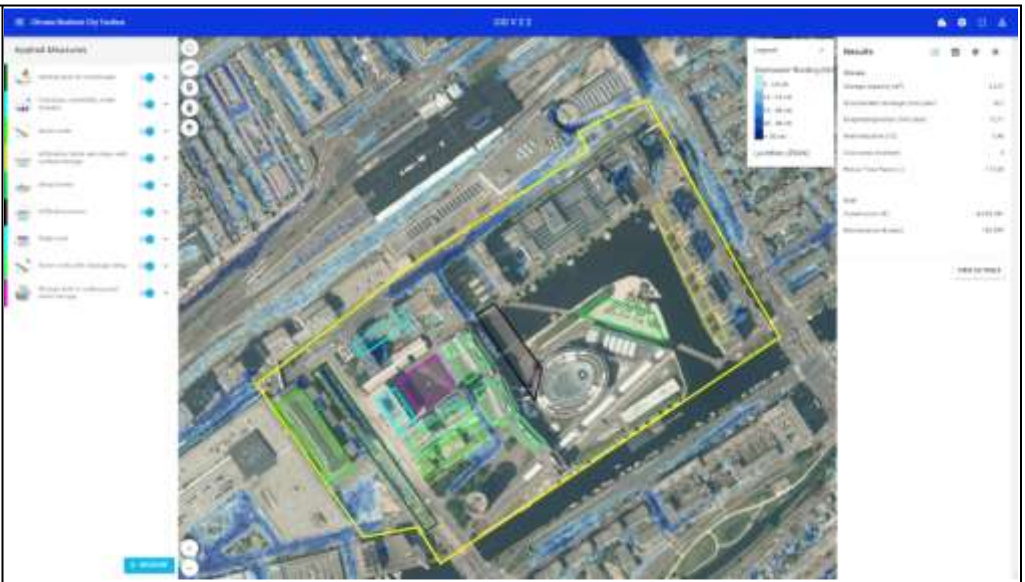
3.1.3 Climate Resilient City Tool (CRCTool)

Overview	
Name of tool	Climate Resilient City Tool (CRCTool)
Tool description (overview)	The Climate Resilient City Tool (CRCTool) aims to support collaborative climate adaptation planning and to promote multi-disciplinary dialogue on adaptation options to increase urban climate resilience. The tool contains a database of over 50 adaptation measures including descriptions, pictures of best practices and references for further reading. The CRCTool is easy to use by both experts and non-experts in the field of urban planning and adaptation and can be used in a workshop setting with multiple stakeholders as well as behind a desk. Tools functionalities allow the users to locate the measures on a map and explore and compare adaptation options for a project area. It provides information on the effectiveness of measures to reduce stormwater flooding, urban heat stress and drought. Additional information on construction and maintenance costs is also available. The CRCTool encourages the use of Nature Based Solutions; traditional grey measures are included to enable comparison.
Main graphic	
Benefits of using the tool	• Create conceptual designs to increase the climate resilience of a certain area that meet defined adaptation targets and are spatially explicit • Support development of local climate adaptation plans and strategies and urban master plans by allowing exploration and testing the feasibility of the plans and strategies based on concrete adaptation measures • Explore and compare potential adaptation options for an area • The tool is user friendly and can be used by both experts and non-experts
Complementarity	The CRCTool can be used in combination with all tools and services that produce maps on climate hazards like the Community Flood Resilience Tool and Heat Tool. The tool can also be used in combination with the Social Vulnerability tool.

Complexity	• The CRCTool has been developed as open source. A free not calibrated version of the CRCTool is freely available online. The tool is very user friendly therefore the complexity of using the tool is low. • The tool configuration must be done by trained users and has medium complexity. • The complexity of creating a new version of the tool based on the source code is high. *Overall level of complexity: Level 2 (customized approach)*
Link to tool webpage	https://crctool.org Documentation can be found on: https://publicwiki.deltares.nl/display/AST/Climate+Resilient+City+Tool+and+KBS+Toolbox+Home
User stories & hub experiences (Decision processes for which City Hubs use the tools e.g. urban planning process, adaptation action plan, SECAP,…)	• In Gdynia the CRCTool is being customized to support multiple potential climate adaptation projects in the city. In the planned workshop climate adaptation will be centered around social vulnerability. • In Lillestrom the CRCTool has being set up for specific redevelopment locations to support the dialogue between the city and project developers on how to redevelop areas and contribute to the climate resilience of the city. • In Athens the CRCTool will be configured to support the planning of Urban NBS for climate resilience for a large redevelopment project.
[Examples – case studies]	Lillestrom: https://lillestrom.crctool.org/en/ Gdynia: https://gdynia.crctool.org/en/ Athens: https://athens.crctool.org/en/
Guidance	
Triple-A Toolkit	The CRCTool is used in the Action phase. The CRCTool supports the identification, evaluation, and prioritization of adaptation measures.
Inputs needed	Data needed to use the tool: - Local rainfall (timeseries) - Local evapo(transpi)ration (timeseries) - Land use type (map) - Vegetation of unpaved areas - Type of Sewer System - Storage capacities - Pumping capacities - Infiltration capacities - Surface water levels - Pumping capacity - Groundwater level - Construction cost (unit prices) - Maintenance cost (unit prices)

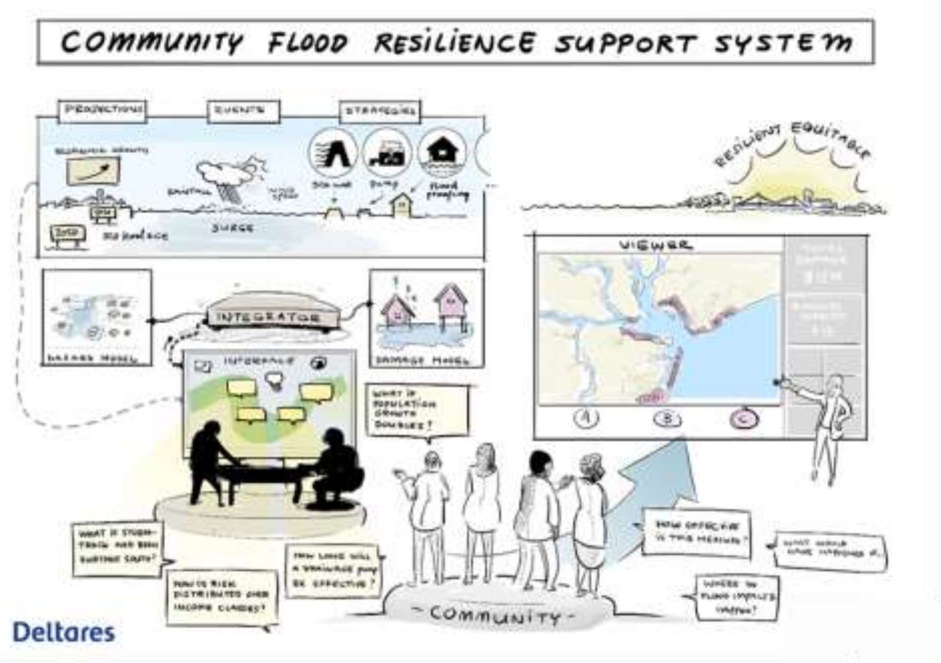
	Difficulty level of inputs needed: Medium difficulty
Methodology	The CRCTool is developed around a central interactive map window that displays base layers like a map and/or aerial photograph that is used as spatial reference. On top of these base layers semi-transparent thematic maps can be displayed like an elevation map, flood or heat stress maps that help to understand the climate challenges in an area and to choose effective locations for interventions. Based on the extent of the project area and properties of the project area that are given in by the user (e.g. soil type, land use scale of interest and relevant climate hazards) a list of adaptation measures is ranked by their effectiveness. The ranking method is based on key figures and a set of rules to combine technical feasibility, site suitability, system capacities and location suitability [1]. The adaptation measures can be drawn on the map as polygon, line or point element and the measure appears in list of applied measures. Based on the main properties of the measure, like water storage depth and contributing area climate resilience and cost Key Performance Indicators are calculated and shown in the user interface. The main KPI's are storage volume, return time factor, additional groundwater recharge, additional evapotranspiration, heat reduction, cool areas, construction costs and maintenance costs. The hydrological KPI's are based on a multi reservoir model: the Urban Water Balance model (https://publicwiki.deltares.nl/display/AST/Urban+Water+balance+model). The effect on heat stress is based on statistical relations and the cost figures are based on unit costs. Results from the model are stored in lookup tables that are accessed by the frontend of the tool to ensure fast result while using the tool. Configuration of the tool for a specific city entails: • Creating a new instance of the crctool.org, e.g. athens.crctool.org • Adding local thematic map layers to the map window • Simulations with the Urban Water Balance Model based on local data to create lookup tables • Optionally, translations of all items in the user interface can be created.

	• Optionally, unit cost based on local cost and currency can be incorporated *Difficulty level of use of approach: Low difficulty*
Outputs	The result of the CRCTool is a conceptual design of a project area with different climate adaptation measures that increase the climate resilience of the area. The results can be saved and exported as: • A project file that can be opened again in the CRCTool (json) • A pdf file that contains: • the map of the selected adaptation measures, • a summary table with all KPI's on the level of the project • A summary table with all KPI's per type of measure • List of applied adaptation measures including a description and images • A geospatial file with the project area and all applied measures and main KPI's (geojson) • A table listing all individual adaptation measures, their properties and KPI's (csv) The outputs can be used for: • communication with a diversity of decision-makers and stakeholders • As input for project pre-feasibility reports • As input for project feasibility phase and project refinement by designers and engineers  *Figure 3: Example for output of CRCTool*

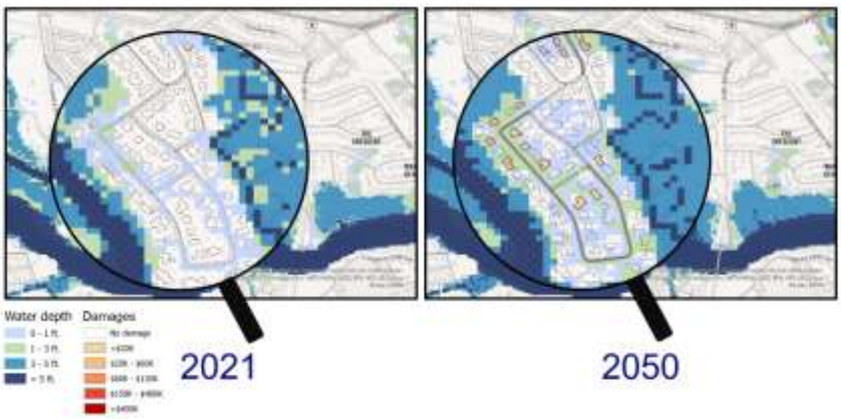
	 *Figure 4: Example for output of CRCTool* *Difficulty level of preparing the outputs: Low difficulty*
Contacts	Who are the contact persons for questions? Reinder Brolsma Deltares reinder.brolsma@deltares.nl
References	The tool: https://crctool.org Documentation: https://publicwiki.deltares.nl/display/AST/Climate+Resilient+City+Tool+and+KBS+Toolbox+Home Publications: McEvoy S., F.H.M. van de Ven, R. Brolsma, J. H. Slinger,Evaluating a Planning Support System's use and effects in urban adaptation: an exploratory case study from Berlin, Germany,Sustainability 2020 https://doi.org/10.3390/su12010173 McEvoy S (2019) Planning support tools in urban adaptation practice. PhD thesis, TU Delft, https://doi.org/10.4233/uuid:48b7649c-5062-4c97-bba7-970fc92d7bbf or https://repository.tudelft.nl/islandora/object/uuid%3A48b7649c-5062-4c97-bba7-970fc92d7bbf McEvoy S, FHM van de Ven, MW Blind, JH Slinger (2018) Planning support tools and their effects in participatory urban adaptation workshops, Journal of Environmental Management, Volume 207, 1 February 2018, Pages 319-333, https://doi.org/10.1016/j.jenvman.2017.10.041 Van de Ven FHM , RPH Snep, S Koole, RJ Brolsma, R van der Brugge, J Spijker, T Vergroesen (2016) Adaptation Planning Support Toolbox: Measurable performance information based tools for co-creation of resilient, ecosystem-based urban plans with urban designers, decision-makers and

	stakeholders, Environmental Science & Policy, Volume 66, 2016, Pages 427-436, https://doi.org/10.1016/j.envsci.2016.06.010 [1] Voskamp IM, Van de Ven FHM (2015) Planning support system for climate adaptation: Composing effective sets of blue-green measures to reduce urban vulnerability to extreme weather events. Building and Environment 83, p 159-167. http://dx.doi.org/10.1016/j.buildenv.2014.07.018

3.1.4 FloodAdapt tool

Overview	
Name of tool	FloodAdapt tool (Formerly known as Community Flood Resilience Support System CFRSS)
Tool description (overview)	The FloodAdapt tool is a decision support tool intended to accelerate climate adaptation actions by making it easier for local and regional agencies to understand their flood risk under different future conditions. FloodAdapt can be used to assess compound flooding, that means any combination of marine, rainfall and riverine flooding, with or without the added effects of future sea level rise, changes in rainfall patterns and storminess and socio-economic developments. The user interface of the FloodAdapt tool makes powerful and efficient flood hazard and impact models easily accessible to users without a computational modeling background. It helps users to define, simulate and visualize flooding scenarios and their impacts and to explore effective strategies to reduce flood risk. Scenarios consist of user-defined or historical weather events, projections of future sea level, climate and socio-economic developments, and user-defined adaptation strategies such as floodwalls, levees, pumps, urban green infrastructure, raising, floodproofing and buying out homes.
Main graphic	 *Figure 5: Illustration of the components of FloodAdapt with the community at its centre*
Benefits of using the tool	The tool aids long-term planning and climate adaptation goals of cities. It can be used, for example, • to prioritize areas for flood risk adaptation, • to develop flood-risk informed zoning plans, • to pre-screen potential adaptation strategies, and • to create visuals for stakeholder engagement. Once set up for the city, the tool empowers city staff to explore different future scenarios and strategies and to create powerful maps of future flood risk for community engagement without the need to hire

	consultants. It is useful for a first screening of options before the assessment of promising options is put out for tender.
Complementarity	The FloodAdapt tool can be used to assess the effectiveness of adaptation options and thus support the design of **adaptation pathways**. The FloodAdapt tool can be used to aggregate flood impacts and risk for areas and groups and can link well with the **Social Vulnerability Index Tool**.
Complexity	The city needs data on topography, bathymetry and building assets and their potential maximum damage and flood damage functions for the initial set up of the tool in a new city. *Overall level of complexity: Level 2 (customized approach)*
User stories & hub experiences	In Cork, the FloodAdapt tool has been set up to support the city council in its long-term flood risk management planning. This decision support system makes it easier to understand flood risk under different scenarios and test various adaptation options. The results can be used to inform adaptation pathways development.
[Examples – case studies]	Not yet available
Guidance	*User Manual (Community Flood Resilience Support System)*
Triple-A Toolkit	The tool can be used in the following Triple-A phases: **Analysis phase:** - Impact assessments for status quo and different future scenarios **Ambition phase:** - Prioritization of areas for adaptation **Action phase:** - Screening and exploring different flood adaptation options, this is prior to and not instead of detailed feasibility and design studies for adaptation
Inputs needed	Once the tool has been set up once for a city, no additional data is needed. The initial implementation requires data on topography, bathymetry and building assets and their potential maximum damages and flood damage functions. *Difficulty level of inputs needed: Medium difficulty*
Methodology	*Text adopted from the User Manual and shortened (see references):* The FloodAdapt tool helps to translate community-oriented questions on future flood impacts and risk into scenarios that can be evaluated by models through the system's user interface. Scenarios are defined in the FloodAdapt tool as a combination of a future projection of climate, sea level rise or socio-economic change, a hydro-meteorological event and an adaptation strategy. The scenarios are fed to the core of the system – the integrator. The integrator automatically translates the user-selected

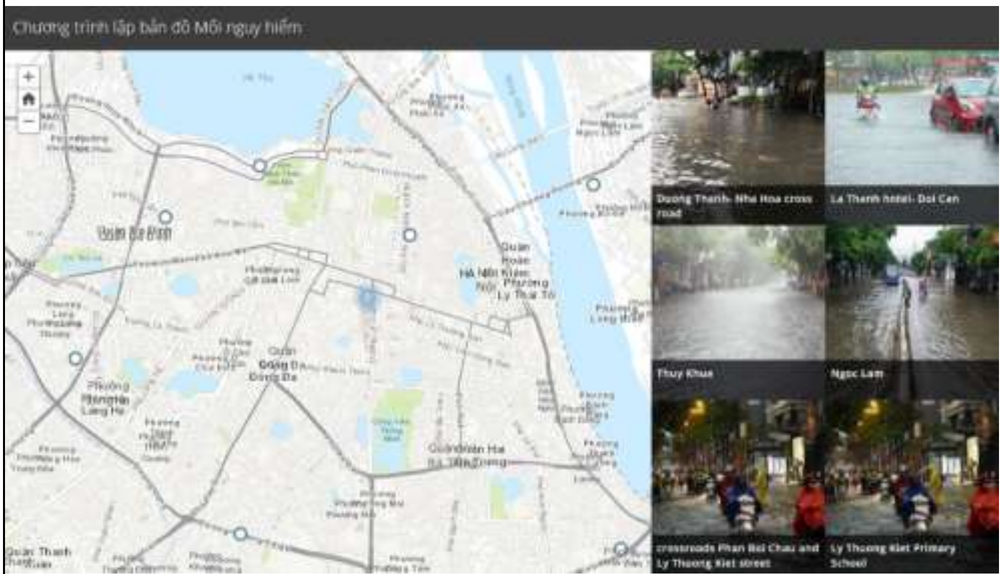
	projection, event, and strategy into the required changes in the flood model and damage model inputs. For example, if the user draws a flood wall, the integrator modifies the flood model input file to include the coordinates and elevation of the new flood wall. This means that once the flood and damage models have been set up for a city or community in the implementation phase, the users do not need to be experienced modelers themselves to perform simulations and explore the flooding and impacts for a range of scenarios. The FloodAdapt tool uses the open-source physics-based compound flood model SFINCS[1], which can accurately predict compound flooding due to surge, rainfall, and river discharge at a fraction of the computation time typically required by physics-based models. The damages to individual buildings and roads are modelled with Delft-FIAT and – when social vulnerability data is available – aggregates these damages over vulnerability classes. *Difficulty level of use of approach: medium difficulty* The user needs some basic understanding of the input data that define an event, a projection and a strategy. The user interface itself guides the user and provides information on what to do. The user manual or a one-day training course have proven to be sufficient to become a proficient user.
Outputs	The flood model creates flood maps in geotiff format, and the damage model saves the tabulated damage data per building and aggregation group to csv or Excel files respectively. In addition, the damage data is saved as shapefile to be imported in GIS applications. The FloodAdapt tool has an export function to prepare a pre-formatted ArcGIS project file that spatially displays the flood depths, damages at asset level, inundation on roads, and aggregated damages with layer formats as in the image below.  *Figure 2. Example results from the FloodAdapt tool comparing flooding (blue hues) and damages to buildings (orange hues) for a major tide event under current and future sea level.* *Difficulty level of preparing the outputs: medium difficulty* The user needs some basic experience with GIS software. The FloodAdatpt tool itself provides all data in GIS compatible formats and

	exports results to an ArcGIS package file so the data can be opened with pre-defined layer formatting.
Contacts	Gundula Winter Deltares gundula.winter@deltares.nl
References	*User Manual (Community Flood Resilience Support System)* *Tutorial (vimeo.com) (Community Flood Resilience Support System)*

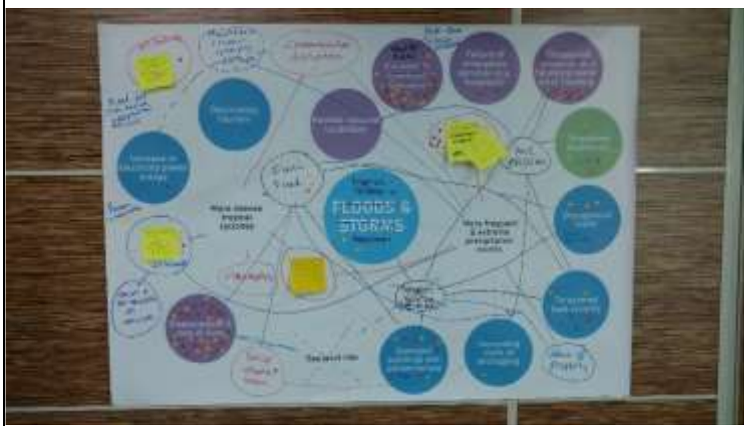
3.1.5 Crowdsource module for climate hazard mapping

Overview	
Name of tool	Crowdsource module for climate hazard mapping
Tool description (overview)	The crowdsource module visualises publicly generated climate data in a digital map. Finding ready-to-use spatial data on climate hazards and vulnerable locations can be a challenge. Local crowdsourcing presents an opportunity to collect this information through methods such as community mapping. Citizens or specific user groups are asked to map climate information via a questionnaire. The resulting dataset can be used to validate technical data or help to prioritise actions. Besides collecting data, the crowdsource module engages citizens and initiates discussion, helping to raise public awareness about climate adaptation.
Main graphic	 *Figure 6: Crowdsource module in Cork, filled by UCC Geography students.* Source: [1]
Benefits of using the tool	The Crowdsource tool is particularly useful for city representatives wishing to plan adaptation action in growing urban centers as it allows to: • Identify areas vulnerable to a climate hazard of interest for the city e.g. heatwaves, flooding. • Validate existing flood/heat maps. • Involve citizens, stakeholders and local organisations by giving them an active role. • Provide the opportunity to use intangible knowledge of citizens to complement scientific knowledge.
Complementarity	The crowdsourcing tool could be used to complement and verify output from other tools such as the Pluvial flood hazard and risk assessment, FloodAdapt tool in urban areas (C3S) and the Thermal Assessment Tool. In addition, the crowdsourcing module can be embedded into the climate stories to support communication.
Complexity	There are both free and commercial software licenses available for tools that support crowdsourcing. If a city has no software available, a license may be costly.

	An example of a commercial tool that can be used is ArcGIS online [2]. A tool based on open-source components is also a possibility but requires programming skills. *Overall level of complexity: Level 2 (customized approach)*
Link to tool webpage	Cork's Climate Change Vulnerability (2022) (https://climadapserv.maps.arcgis.com/apps/mapviewer/index.html?webmap=8ba487b09b2140639079f4069188c4fa)
User stories & hub experiences	The tool has been used by students of the university of Cork. A tailored questionnaire (https://storymaps.arcgis.com/stories/bd89e69f3c264dc193579646ce87e776) has been designed to gather climate information from students. At this stage, 49 inputs have been gathered and the current outcome can be visualized in a digital map (https://climadapserv.maps.arcgis.com/apps/mapviewer/index.html?webmap=8ba487b09b2140639079f4069188c4fa). The map shows potential vulnerable areas or objects accompanied by pictures. Examples include floodplains, low bridges, clogged water drains and flooded areas.
Guidance	
Triple-A Toolkit	The tool can be used in the following Triple-A phases: • Analysis phase to find vulnerable areas in the city. • Action phase to validate / ground-truth model data or help to prioritize.
Inputs needed	No data is needed for the initial set up of this tool as its function is to collect data. The only input needed is a questionnaire from the city that can be filled with information by citizens. For decision makers to later make use of the tool to define Action it should be populated with spatial data about hazards and vulnerable areas as acquired through the questionnaire. *Difficulty level of inputs needed: Low difficulty*
Methodology	To use the crowdsourcing tool, a city need to follow the next steps: 1. Determine the aim of the crowdsourcing tool. Questions to ask here are: who do you want to reach? What hazard do you want to focus on? What information are you looking for? 2. Make a questionnaire for the information you want to collect from your users. For example, you can ask your user to describe the location, whether the location is flooded, if it is still accessible, and add a picture. 3. Link the results from the questionnaire to a clickable map automatically. As a result, your map will show the different locations of where data is collected. In this step you can consider to first do a quality check on submitted data to ensure that the filled forms are complete and relevant.

	4. After setting up the crowdsourcing module, it needs to be tested by a group of users, for example, students. The feedback needs to be collected and adjustments in the questionnaire can be done. 5. The last and probably most important step is the dissemination of the crowdsourcing tool. *Difficulty level of use of approach: medium difficulty*
Outputs	The outcomes from the crowdsourcing tool can be presented in a clickable map. For each location described in the questionnaire, a point is created on the maps. Users can click on a point to find out more about that specific location. The data is also available in a spreadsheet. The data is very *easy* to interpret.  *Figure 7: Example of crowdsourcing outcomes, as was implemented in Hanoi, Vietnam (2020).* *Difficulty level of preparing the outputs: Low difficulty (But there would need to be someone quality checking to remove potential spam and irrelevant input.)*
Contacts	Koen Veenenbos Climate Adaptation Services koen@climateadaptationservices.com Sophie van der Horst Climate Adaptation Services sophie@climateadaptationservices.com
References	[1] Cork's Climate Change Vulnerability (2022). https://storymaps.arcgis.com/stories/bd89e69f3c264dc193579646ce87e776 [2] Crowdsource Manager (2022). https://solutions.arcgis.com/local-government/help/crowdsource-manager/

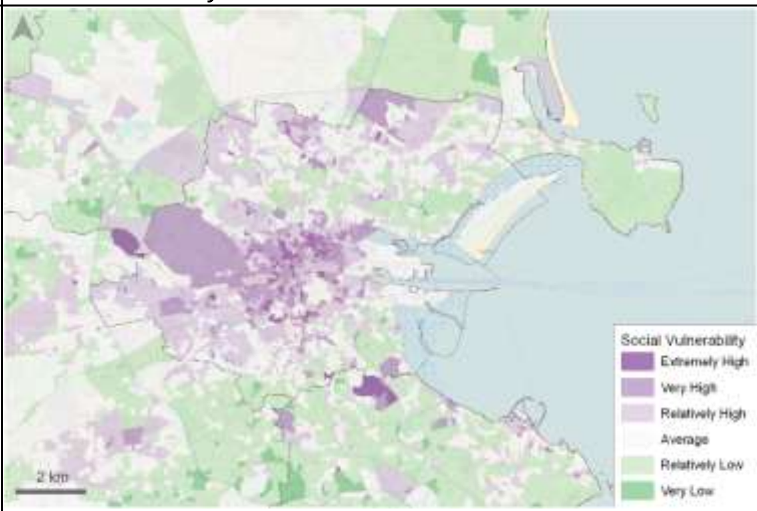
3.1.6 Climate Impact diagrams

Overview	
Name of tool	Climate Impact Diagrams
Tool description (overview)	Climate impact diagrams aim to build a shared understanding among all city stakeholders on the opportunities and risks of climate change for the different city sectors. It is a first step to start the conversation about climate change adaptation and work towards a joint approach for taking climate measures, identifying co-benefits and offering ideas for action. Impact diagrams present a simplified, visual summary of current scientific knowledge of climate effects and climate consequences in a city. The diagrams help to gain more insight into opportunities and risks and can kickstart the search for additional knowledge or collaboration partners.
Main graphic	 *Figure 8: Example of an impact diagram* Photo by CAS.
Benefits of using the tool	The impact diagrams are a decision support tool that are appealing for policymakers. They visualise possible outcomes for those making climate investment decisions and enhance dialogue between science and policy. They offer a visual summary of the climate change impacts by sector (economic, social and natural) in order to contribute to the development of adaptation plans. Impact diagrams can help cities and city staff to gain insight into the opportunities and risks of climate change for their own field of work, and can enable focussed discussion between stakeholders about adaptation options and priorities.
Complementarity	Are there any other REACHOUT tools (or other tools outside of REACHOUT) that this tool works well with?

	The tool begins with a city specific analysis of climate trends, based on models and observations. All REACHOUT tools that are able to describe such trends work well with the development of climate impact diagrams. These include for example the Thermal Assessment Tool (Tecnalia), Community Flood Resilience Support System (Deltares) and Pluvial flood hazard and risk assessment (CMCC).
Complexity	The impact diagrams workshop can be organised by cities on their own, but for a more thorough approach, it is necessary to bring climate science expertise to the workshop (e.g., from the national meteorological service). *Overall level of complexity: Level 1 (Ready-to-use light approach)*
Link to tool webpage	
User stories & hub experiences	In REACHOUT Logroño has used this tool to prepare for the Sustainable Energy and Climate Action Plan (SECAP). [Link to the story maps of the city hubs] https://cas-platform.com/REACHOUT/Logrono/
[Examples – case studies]	[Link to the story maps of the city hubs] https://cas-platform.com/REACHOUT/Logrono/ Impact diagrams were first presented in the Dutch National Climate Adaptation Strategy (2016) to complement the IPCCs climate change assessments with national climate scenarios and sector specific impacts.
Guidance	This tool is developed on the basis of a workshop, in which draft impact diagrams are validated and prioritized. Using the prioritised impacts, the key climate risks for the city are identified. For a practical guide on how to develop impact diagrams and organize a workshop, please refer to the Climate impact diagrams & risk workshop guide.
Triple-A Toolkit	The tool can be used in the following Triple-A phases: • Analysis phase to identify and prioritize climate impacts of a city or region. • Ambition phase to collaboratively create sectoral climate impact chains that provide more information on the opportunities and/or risks of climate change.
Inputs needed	• A city specific analysis of climate trends, based on models and observations, which includes: • Identification of climate hazards most relevant for a city. • Analysis of any observed historical trends in the climate (experts should be involved for correct interpretation of the climate data). • Analysis of future projections for these hazards, where a city needs to select relevant climate scenarios and time horizons (experts should be

	involved for correct interpretation of the climate data). *Difficulty level of inputs needed: Low difficulty* Gathering information on climate trends can be challenging. Some cities may have access to tailored studies for their city, while others may only have access to national-level or even European-level data and information.
Methodology	The workshop will take approximately half a day. Please refer to the Climate impact diagrams & risk workshop guide for a step-by-step explanation on how to carry out an impact diagram workshop where you validate sector-based impacts with city stakeholders.  *Figure 9. The main three steps of the methodology* The guide contains a draft agenda and list of materials needed. *Difficulty level of use of approach: Low difficulty*
Outputs	The workshop will result in sector-based, validated impact diagrams for a city. *Difficulty level of preparing the outputs: Low difficulty*
Contacts	Felix van Veldhoven Sophie van der Horst Timo Kelder Climate Adaptation Services (CAS) info@climateadaptationservices.com

3.1.7 Social vulnerability tool

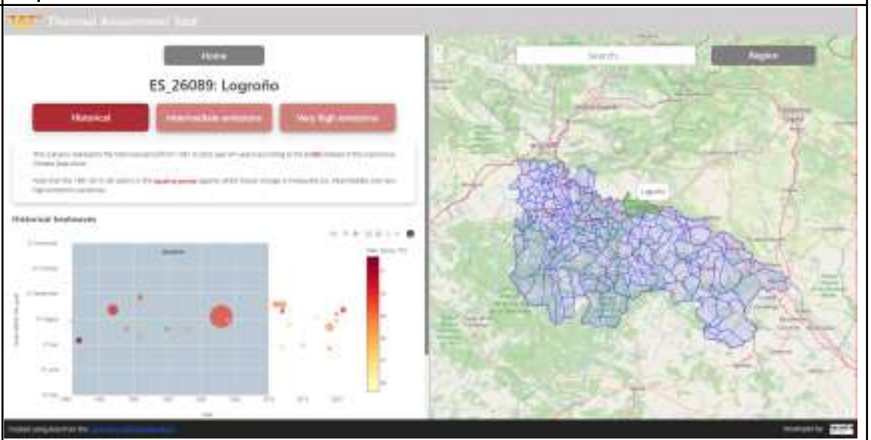
Overview	
Name of tool	Social Vulnerability Index (SVI) Tool
Tool description (overview)	This tool is designed to help users to assess communities' vulnerability to climate hazards such as flooding, extreme heat and drought. The tool compiles census data for indicators such as housing quality, unemployment rate, and average education levels (amongst others) to analyze the vulnerability of a given community to climate change. The tool also provides an index or score of socio-economic vulnerability for each census-defined small area within a region of interest. These data can be used in tandem with assessments of bio-physical impacts from climate change or can be used as a standalone resource to inform decision-making. The data provided by this tool allows users to better understand climate change risks for a given community, and to compare risks across regions using an easy-to-use map interface. The tool is intended to support decision-makers in municipal government and in industry sectors such as transport, water and agriculture, to assist both climate change adaptation and the transition to a carbon neutral economy.
Main graphic	 *Figure 10: Example of social vulnerability mapping provided by the SVI tool interface*
Benefits of using the tool	• Provides an easy-to-use interface allowing users to quickly examine and visualize zones of relative socio-economic vulnerability. • Can be updated as new census data is collected. The indicators that comprise the index can also be tailored to flooding and heat stress, if needed.

	• Complements bio-physical impact assessments to help users to understand the relative sensitivity of any particular location to a given climate hazard. • Provides important socio-economic data for the development of climate change adaptation, disaster risk management, and urban and regional development plans.
Complementarity	This tool can be used effectively in combination with several other REACHOUT tools to better understand climate change impacts and risks. For instance, social vulnerability index (SVI) data can be incorporated into damage model layers of the Community Flood Resilience Support Service tool delivered by Deltares. SVI data can also be used in conjunction with the Dynamic Adaptation Policy Pathways (DAPP) generator (Deltares), and with the Crowdsourcing Tool (CAS) to inform adaptation planning decisions of local government. Additionally, the social vulnerability maps regarding the heat hazard can also be integrated with the heatmaps developed by Tecnalia to better visualize the risk.
Complexity	Implementation only with support of tool developers/consultants *Overall level of complexity: Level 2 (customized approach)*
Link to tool webpage	The user interface for the SVI Tool is currently under development and a draft version can be shared with tool users in the interim.
User stories & hub experiences (Decision processes for which City Hubs use the tools e.g. urban planning process, adaptation action plan, SECAP,…)	**Cork**: is using the SVI Tool in combination with all three of its other REACHOUT tools, and as part of its statutory obligations to develop and implement a Local Authority Climate Action Plan in 2023. **Athens**: is using the SVI tool to identify areas of high vulnerable population density and combine to the output of Thermal Assessment Tool – this will allow Athens to target better its heat-related work. **Logroño** is using the tool to better define and understand the SVI about the heat and flood hazard and be able to identify areas (neighborhoods) of high social vulnerability. Additionally, Logroño is interested in combining the social vulnerability outcome maps with the Thermal Assessment Tool – heatmaps, to better target its heat-related risk. **Gdynia**: will use the SVI Tool in conjunction with the Climate Resilient Cities Tool in order to support spatial adaptation decisions for the city.
[Examples – case studies]	[Link to the story maps of the city hubs]

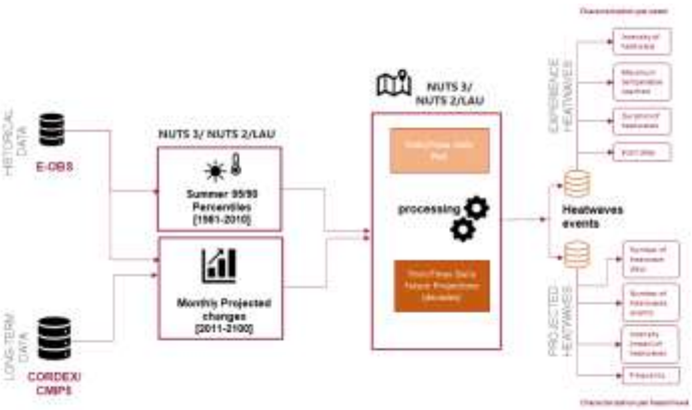
Guidance	
Triple-A Toolkit	The tool can be used in the following Triple-A phases: **Analysis phase**: • The SVI Tool can be used directly by decision-makers for the purposes of understanding a community's socio-economic vulnerability. Alternatively, it can used in conjunction with other impact and risk analysis methods and tools to assess climate change risks **Ambition phase**: • The SVI Tool can be used to directly inform decision-makers' risk prioritization and identification of objectives **Action phase**: • The SVI Tool can help decision-makers to identify, evaluate and prioritize the most robust and equitable adaptation measures
Inputs needed	The Social Vulnerability Index is compiled from a collection of 25–30 generic socio-economic variables collected from national census databases at the smallest area scale. Indicators are then categorized into domains such as population age, health, education, accommodation type and tenure, and income. The index can also be tailored for a specific climate change hazard using Copernicus climate model data. This involves choosing census data/indicators specifically relevant to a hazard of choice and weighting those hazard-specific indicators appropriately. *Difficulty level of inputs needed: High difficulty (needs a lot of data and/or expertise to operate* The SVI uses the coding language R in an application that collects census data, compiles index scores by Census small area geographic locations and maps those index scores through Arc-GIS software.
Methodology	The tool involves an application developed using coding language R. The application compiles census data into index scores for each Census small area location, and maps those data via Geographic Information Systems software (Arc-GIS) Each small area is colour-coded in relation to its relative vulnerability. Colour-coding uses a 7-point scale from Extremely High to Extremely Low.

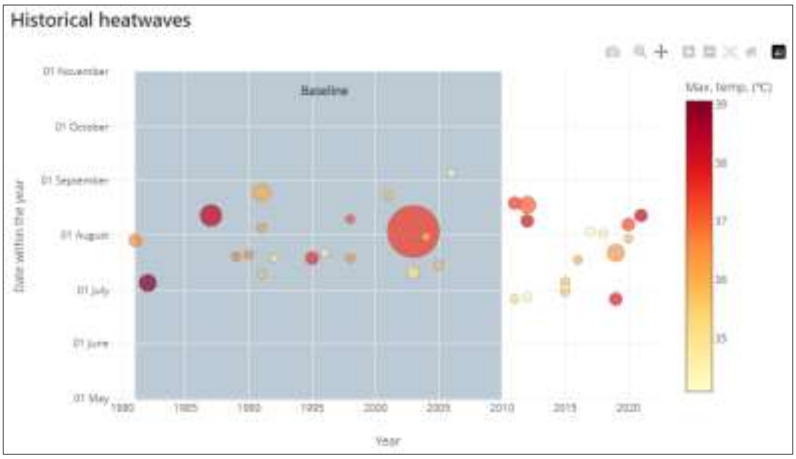
	The choice of indicators and indexing methodology can also be tailored to flooding and heat stress, as needed. *Difficulty level of use of approach:* High *difficulty (needs a lot of expertise to operate / needs support of tool developers)* The index development will require input from the tool developer. Once the data are collected and mapped, however, the user interface will be easy to use and to navigate.
Outputs	The SVI Tool provides both datasets and Arc-GIS maps of index scoring across the geographic area(s) of interest. The underlying dataset can also be incorporated into other tools for the purposes of impact and risk assessment. The data and maps produced by the SVI Tool will allow decision-makers to understand varying socio-economic vulnerability across their communities. This data can also directly inform the development of climate change planning and policy. *Difficulty level of preparing the outputs: High difficulty (needs a lot of expertise to postprocess)* The development of SVI index scores will need the tool developers' expertise in the first instance, but once compiled, the tool provides an easy-to-use dataset and maps
Contacts	Denise McCullagh (UCC) – denise.mccullagh@ucc.ie
References	An overview of the methodology: Fitton, JM, O'Dwyer, B, Maher, B (Forthcoming) 'Developing a social vulnerability to environmental hazards index to inform climate action in Ireland'. *Irish Geography,* 54(2), 157-180 An example of the user interface for the SVI Tool is currently under development and a draft version can be shared with tool users in the interim (available upon request).

3.1.8 Thermal Assessment Tool

Overview	
Name of tool	Thermal Assessment Tool
Tool description (overview)	Climate change is leading to an increase in the frequency and intensity of heatwave events across the globe. The Thermal Assessment Tool (TAT) assesses and visualizes the thermal behavior of regions and cities in Europe during episodes of extreme heat to better understand this phenomenon to improve the adaptative capacity and support climate adaptation plans. The tool provides the frequency and severity of past, present and future extreme heat episodes under intermediate (RCP4.5) and very high (RCP8.5) emissions scenarios at different regional scales (municipality, province and/or autonomous community). The tool characterizes the magnitude of these extreme heatwave events in Europe based on different risk levels (warning, alert, alarm), which were defined based on the severity of their potential impacts.
Main graphic	 *Figure 11: Panel that shows the historical heatwaves of a specific region (e.g. Logroño)* Source: Tecnalia
Benefits of using the tool	The tool allows end-users and decision-makers to easily visualize how long, intense and frequency will extreme heat events be in the coming decades considering the intermediate (RCP4.5) and very high (RCP8.5) emissions scenarios. This rise awareness on citizens and support governments to prepare and protect the city through effective policy making
Complementarity	The Thermal Assessment Tool works especially well in combination with the **Social Vulnerability** tool to assess and visualize the risk considering heat hazard and heat related social vulnerability. It could also be an input for the **CRCTool** as a heat stress map layer that helps to understand the climate challenges in an area and to choose effective locations for interventions.

Complexity	An online version of Thermal Assessment Tool is freely available to visualize past and future heatwave plots. The tool is based on the independent and authoritative Copernicus Climate Change Service (C3S) datasets. The complexity of using the tool is **low**. This first online version of the Thermal Assessment Tool includes the heatwave service, but not the heatmaps service which has been developed offline so far. The complexity of creating the maps as tailored version for each city - based on the earth observation data and source code is **high**. *Overall level of complexity: Level 1 (Ready to use light approach)*
Link to tool webpage	https://thermal-assessment.urban.tecnalia.dev/
User stories & hub experiences	**Logroño** is using the tool to plan future city interventions and as an input for the SECAP. Logroño has also included the outcomes of the tool in their climate story (link) to raise awareness among citizens about heatwaves impacts which are becoming more frequent and intense in the city. **Milano** is interested in the regional perspective of the tool outcomes and prevision for the future as well as planning for the energy community. Milano has also included some outcomes of the tool in their climate story (link) to better visualize future impacts. **Athens** is interested on heatwaves projections and heatmaps to determine those areas of higher surface heat concentration.
[Examples – case studies]	Link to the Logroño user story Link to the Milano story map
Guidance – Heatwave service	Note. The Heatmaps Service guidance will be added during next year – once the heatmaps are online available.
Heatwave service overview	This service provides interactive maps and plots to visualize the frequency and severity of heatwaves at different regional scales in Europe for both the historical period 1981-2021, and the projected 30-year periods from 2011-2040 to 2071-2100, in 10-year steps using different future climate change scenarios.
Triple-A Toolkit	The tool can be used in the following Triple-A phase: • Analysis phase to support the heat hazard assessment considering the intermediate (RCP4.5) and very high (RCP8.5) emissions scenarios.
Inputs needed	The **Heatwave service** of Thermal Assessment Tool uses public, independent and authoritative Copernicus Climate Change Service (C3S) data as a way to obtain homogeneous data for the whole EU. The input variables are maximum and minimum daily temperature obtained from the next C3S datasets: • **e-OBS [1950 to present]**: This dataset provides daily gridded land-only observational data over Europe. [1]

	• **EURO-CORDEX [2011-2100]**: This dataset provides the future regional climate conditions, according to an ensemble of EURO-CORDEX dataset. [2] The complexity of obtaining and processing the raw data from C3S at different regional levels is **high.** *Difficulty level of inputs needed: High difficulty*
Methodology	A heatwave is a prolonged period of extremely high temperature for a particular region. As there are multiple nation specific definitions at this stage this application makes use of a generic health communtiy definition: a heatwave is defined as a period of two or more days with excessively high temperatures, relative to the usual climate in the area and relative to normal temperatures for the summer season. At first, the **percentiles 95 and 90** of maximum and minimum temperature, respectively, are obtained considering the values of maximum and minimum temperature of the different regional scales (according to NUTS classification) [6] and considering the summer months (**June**, **July, August and September**). The baseline period used to estimate the reference heatwaves goes from **1981 to 2010.** Secondly, maximum and minimum daily temperature historical and projected records are considered. Since the climate models typically provide a biased projection of the future it has been necessary to adjust the bias projections to obtain actual trends of what will happen in the future regarding the studied phenomenon. To do so, a **delta-scaling method** is performed to calculate the biases (perturbation) of each ensemble. Afterwards, this perturbation is added to the observations to get the bias-adjusted projections.  *Figure 12: Heatwave service processing workflow* In a last step, the heatwaves events, which are characterised using the start date, duration, maximum temperature, and intensity, are categorized in **three risk levels**:

	- **Yellow level/Warning Level**: This level is considered when there are 2 consecutives hot days that exceed the corresponding percentiles. Some specific activities might be affected. Generates a situation of **warning**. - **Orange level/Alert Level**: This level is considered when there are 3 or 4 consecutives hot days that exceed the corresponding percentiles. The impact damage might be significant for some sectors. Generates a situation of **alert**. - **Red level/Alarm Level**: This level is considered when there are 5 or more consecutive heatwave days that exceed the corresponding percentiles. The material damage can be very high. It generates an **alarm** situation. *Difficulty level of use of approach: High difficulty*
Outputs	The outcomes of the Thermal Assessment Tool are the following customized panels: - **Historical heatwaves panel**: This panel is composed by an interactive plot that shows the historical heatwave events that took place between 1981 to 2021 in a specific region. Each bubble represents a heatwave event. The bubble's colour represents the maximum temperature reached during that event and the size represents the duration of the heatwave. Moving the mouse over each bubble allows to get specific information on the starting date, maximum temperature, severity and duration of the heatwave event. The plot also allows to zoom in or zoom out to better visualize different heatwave events happened in the past.  *Figure 13. Historical heatwaves* - **Projected heatwaves panel:** This panel is composed by two interactive plots, visualizing the evolution of the frequency of heatwave events and delivering the number of heatwave days per hazard level in a specific region. - **Frequency of heatwaves per decade:** This plot shows the future evolution of the heatwaves for each

hazard level. The yellow, orange and red lines show how frequently the warning, alerts and alarms events will happen in the future. The frequencies are provided as the average number of events of a specific hazard level per decade. To estimate the average, 30-year periods are considered. The baseline period considered is 1981-2010, while the future ones go from 2011-2040 to 2071-2100, in 10-year steps. Thus, the future decades in the x-axis represent the last decade of the corresponding 30-year window. The uncertainty is given in a best vs. worst case way (i.e. the model that predicts the lowest number of events will be the best case, while the one that predicts the highest will represent the worst case).

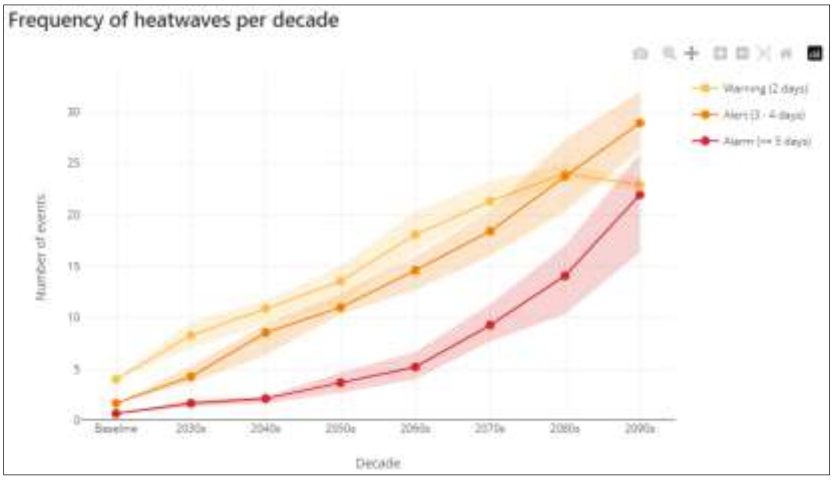


Figure 14. Evolution of the heatwaves's frequency per decade

- **Heatwave days per year:** This plot shows the evolution of the average number of heatwave days per hazard level. The yellow, orange and red bars show the number of warning, alerts and alarms days that will happen in the future. The days are provided on an annual basis. To estimate the average, 30-year periods were considered. The baseline period was 1981-2010, while the future ones went from 2011-2040 to 2071-2100, in 10-year steps. Thus, the future decades in the x-axis represent the last decade of the corresponding 30-year window.

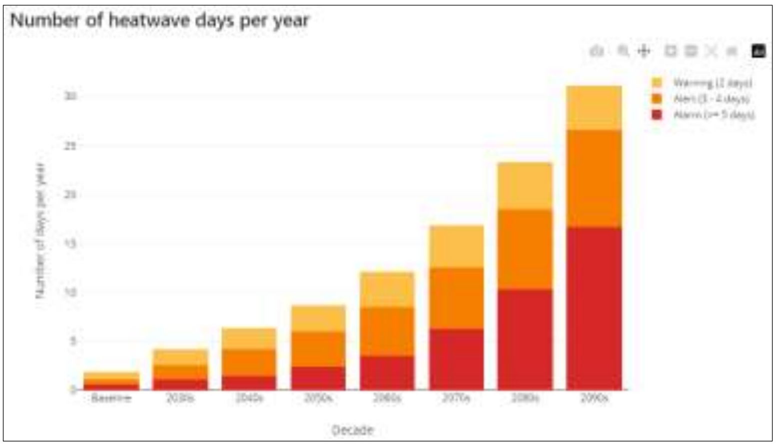


Figure 15. Evolution of the heatwave days per year

The user selectable parameters of the heatwave service of the Thermal Assessment Tool are the following:

- **Selectable regions:** This map shows the EU regions for which the heatwave information is available. *The user can zoom in and zoom out to select NUTS2, NUTS3 or Local Administrating Units.*

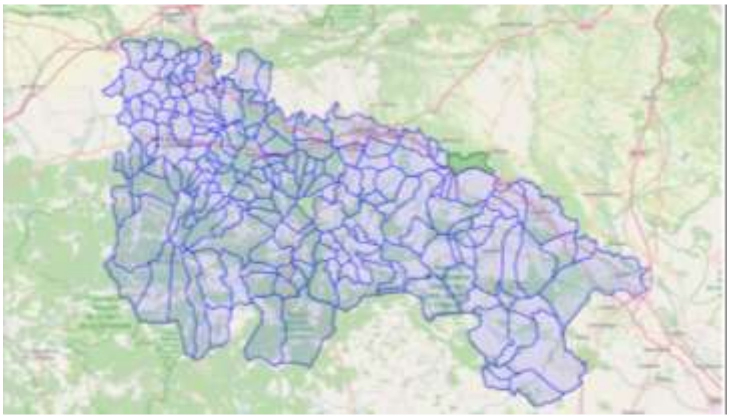


Figure 16. Geographical selectable map to select the region/city

- **Selectable scenarios:** This panel allows to select three possible scenarios: the *historical record* (1981-2021), the *intermediate emissions* scenario (2011-2100) – considering future regional climate conditions, assuming an intermediate greenhouse gases and aerosols emissions scenario (RCP 4.5) - or the *very high emissions scenario* (2011-2100) - which represents the future regional climate conditions, assuming a very high greenhouse gases and aerosols emissions scenario (RCP 8.5)

The outputs can be used:

- for communication with other stakeholders

	- to improve the *adaptative capacity* of regions and cities - As input to support different stakeholders in the design of *adaptation plans* and *regional policies* *Difficulty level of preparing the outputs: High difficulty*
Contacts	*TECNALIA* *Joshua Lizunda Loiola; joshua.lizundia@tecnalia.com* *Nieves Peña Cerezo; nieves.pena@tecnalia.com*
References	*[1]* E-OBS daily gridded meteorological data for Europe from 1950 to present derived from in-situ observations available at Copernicus Climate Data Store (CDS). More info *[2]* Coordinated Regional Climate Downscaling Experiment - CORDEX *on single levels* available at Copernicus Climate Data Store (CDS). *More info* *[3]* E-OBS daily gridded meteorological data for Europe from 1950 to present derived from in-situ observations available at Copernicus Climate Data Store (CDS). More info *[4]* Coordinated Regional Climate Downscaling Experiment - CORDEX *on single levels* available at Copernicus Climate Data Store (CDS). *More info* [5] Landsat 8 satellite data. Landsat Collection 2 L2SP images were obtained from the EarthExplorer (https://earthexplorer.usgs.gov/, last accessed in September 2022) webpage of the United States Geological Survey (USGS). [6] Europe Regional Scales NUTS 2021 classification lists 242 regions at NUTS 2 and 1166 regions at NUTS 3 level. More info at https://ec.europa.eu/eurostat/web/nuts/background *[7]* EarthExplorer (EE) provides online search, browse display, metadata export, and data download for earth science data from the archives of the U.S. Geological Survey (USGS). EE provides a user interface at https://earthexplorer.usgs.gov/ (last accessed in September 2022) [8] The Copernicus Land Monitoring Service (CLMS) provides geographical information on land cover/land use and on variables related to vegetation state, water cycle and earth surface energy variables. More info at https://land.copernicus.eu/

3.1.9 Climate Stories

Overview	
Name of tool	Climate stories
Tool description (overview)	Climate stories are a form of structured communication designed to share information, experiences, and targeted messages about climate change/adaptation. Ideally, stories are compelling and entertaining and combine text with supporting media or scientific data. The target audience can be the public or specific group(s). The story can be used to convey all kinds of publicly important messages about climate change. Defining the audience and the core message are essential components in the development process so that the story appeals to the audience and the core message can be communicated clearly.
Main graphic	 *Figure 17. Example of Climate story - Logroño*
Benefits of using the tool	Stories have the potential to increase the impact of the climate message you want to communicate; from making people feel what climate risks entail in real-life settings to calling for action. Possible benefits are: • Climate change issues become personal and tangible • Learn about climate change and its impacts. • Learn about how climate hazards affect citizens’ lives. • Generate a sense of urgency about what climate resilience entails.

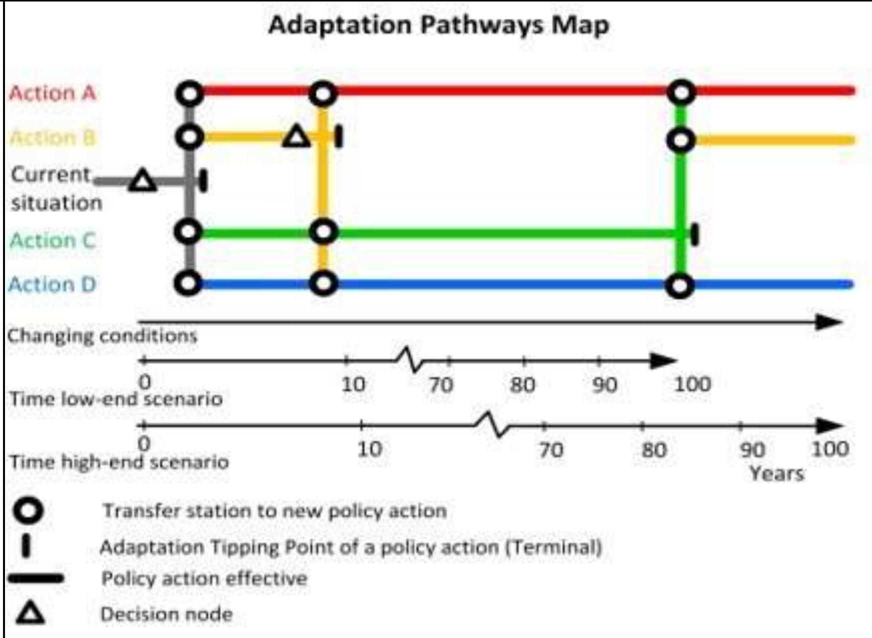
	• Identify and understand possible climate actions that are being taken/or can be taken.
Complementarity	The climate story is highly versatile and can integrate the results of any climate tool. Climate tools that produce easy-to-understand visuals are easiest to integrate into a climate narrative. Map-based tool outputs are especially impactful. The creative process of developing a climate story helps identify needs for new outputs or products from the tools, for example developing easy to understand infographics expressing some of the more complicated scientific content of the tools.
Complexity	The level of complexity is completely dependent on the ambitions of the story. The development of the climate stories requires an iterative approach between the technical developers and the city representatives. A good and engaging narrative takes time to develop. In addition, access to high quality media (images, maps, plots, videos) greatly improves the ability to create a compelling and impactful story. Implementing the story requires a platform as a basis– this can be as simple as a document, or as complex as a specialised story mapping software. *Overall level of complexity: Level 1 (Ready to use light approach)*
Link to tool webpage	https://reachout-cities.eu/climate-stories/
User stories & hub experiences (Decision processes for which City Hubs use the tools e.g. urban planning process, adaptation action plan, SECAP,…)	Each City Hub is developing a climate story. The following topics are currently under development: The cities of Logroño, Milano, and Athens focus on heat impacts in their stories. They target citizens and municipal departments to provide insight into the impacts of heat on specific vulnerable groups (children, outdoor workers, elderly). The Athens story for example describes a day in the life of Grandmother Sophia and her grandchildren during a heatwave. The stories for these cities also describe what is being done by the cities and what action citizens and other stakeholders can take to become more heat resilient. Results from the Thermal Assessment Tool (Tecnalia) and Social Vulnerability to Environmental Hazards Index tool (UCC) are woven into the story. The cities of Lillestrøm, Cork, and Gdynia focus on flooding impacts in their stories. They target citizens, municipal departments, and other relevant stakeholders engaged in city planning. The stories show the impacts of flooding on peoples' daily lives and explain the actions that can be taken by different types of stakeholders. The stories are also used to explain what the city is doing about flooding and why. Results from the Community Flood Resilience Support Tool (Deltares) and the Social Vulnerability to Environmental Hazards Index tool (UCC) will be integrated into the stories where relevant.
[Examples – case studies]	All climate stories will be accessible to the public via URL links as they are completed and published.

	After the first development cycle (year 1 of the project), several climate story prototypes are available through password-protected links and as static PDF copies. An example is the climate story for Logroño. The story addresses the problems associated with heat and how it affects children. The story follows the experiences of a couple of school kids during the course of a typical early summer day, including a morning discussion with their parents, learning about climate change impacts at school, and travelling through the city to their Grandparent’s house in the afternoon. Future projections for heatwaves, the effects heat has on vulnerable persons, and actions the city is taking to mitigate the problem are woven into the story.
Guidance	
Triple-A Toolkit	It can be relevant for any of the phases of the Triple-A toolkit: **Analysis phase:** • Provide insight into the climate change trends, hazards, impacts, risks, and damages, for example, to create awareness or increase support for developing adaptation policy. **Ambition phase**: • Show what a climate-resilient city could look like or communicate about adaptation goals and targets. **Action phase**: • Show what actions can be taken by whom.
Inputs needed	The inputs required are entirely dependent on the objectives of the climate story to be developed. In general, the development of the climate stories benefits from high-quality media (photos, images, data plots, videos). GIS/map data is also a powerful source of information. The story also benefits from establishing a subtle emotional/psychological connection to the intended audience, for

	example using locations and references the target audience is familiar with. These inputs can be gathered from a variety of sources: General media can be collected by photographers or artists, GIS data from the municipality or national mapping authority, media presenting scientific data can be created by climate tools, or from other relevant sources. The development of the story benefits from the involvement of representatives of the target audience, as well as intended owners of the completed story (for example planning officials). Information gathering and story development may be enabled by workshops and direct collaboration between these groups. *Difficulty level of inputs needed: Medium difficulty*
Methodology	The idea of the climate story is to develop a narrative. This can be achieved using, for example, the classical storytelling structure of a hero, a path, an objective, a trigger, and a resolution. An example of this narrative structure is the story of Little Red Riding Hood (hero), who will visit her grandmother (objective), and while on the way strays from the road into the woods (path), is endangered by the wolf (trigger) and is saved by the huntsman (resolution). Other narrative structures may be more relevant depending on the cultural context of the target group or the city. Developing the narrative is a creative collaborative process: • First, the intended audience and the objective of the climate story are defined. This requires involving the ‘owners’ of the climate story, e.g. the organisation or persons who have a message to be communicated to the audience. • Next, the trigger (or call to action) in the story is identified, and how this can influence the path of the story to a resolution. In addition to the ‘owners’, individuals from the target audience can be involved to help identify a connecting point, e.g. a person/event/local history/community value etc. The intention is to find an emotional connection between the message and the audience, as this connection helps the audience to fully engage in the story and the developing message. • Finally, supporting data / information / models / maps or other necessary elements are identified. This stage can benefit from the involvement of media producers (photographers/videographers), artists, GIS specialists etc. Once these building blocks are in place, the narrative is developed as a manuscript, in the form of scenes or phases, and the needed visual imagery and supporting documentation is identified. At the final stage the manuscript and supporting media are implemented in the presentation platform (a document, a story map, a presentation, etc.)

	Difficulty level of use of approach: High difficulty (first time), Medium difficulty (with some experience)
Outputs	The output depends on the platform for the implementation required by the stakeholder to develop and maintain the story during and after the project period. Platforms may include story mapping software, text documents, presentations, videography etc. *Difficulty level of preparing the outputs: Low to High difficulty, depending on the specific platform the story owner selects and the level of competency they possess.*
Contacts	• Felix van Veldhoven, CAS • James Strout, NGI

3.1.10 Adaptation pathway generator tool

Overview	
Name of tool	Adaptation pathway generator tool
Tool description (overview)	The Pathways Generator Tool (PG) develops pathways maps to define the solution space and allow comparison of alternative pathways into the future, via evaluations of costs, benefits and co-benefits. Together, DAPP and the PG have been used for flood risk in Miami, water supply in San Francisco and coastal flooding in Aveiro, Portugal, among others.
Main graphic	 *Figure 18. Example of Adaptation Pathway Map*

Benefits of using the tool	It allows decision makers to consider longer-term implications and path dependency of near-term decisions to avoid investment regret and lock-in as the uncertain future unfolds. It uses 'tipping points' based on bottom-up vulnerability assessments and defined with stakeholders to ensure that system performance is maintained under a variety of futures. It can be used with different levels of analysis from qualitative expert judgement to quantitative modelling results.
Complementarity	The pathways generator complementary tools are Community Flood Resilience Support System and Climate Resilient Cities Toolbox.
Complexity	*Overall level of complexity: Level 1 (Ready to use light approach)*
Link to tool webpage	Download the executable onto your computer to start using it.
User stories & hub experiences (Decision processes for which City Hubs use the tools e.g. urban planning process, adaptation action plan, SECAP,…)	Cork is working with this tool for adaptation to floods (in connection with developing Climate Resilient Development Pathways).
[Examples – case studies]	
Guidance	
Triple-A Toolkit	The tool can be used in the following Triple-A phases: Ambition phase: • The PG Tool supports the mapping and visualisation of the solution space Action phase: • The PG Tool can help decision-makers to identify, evaluate and prioritize the best pathway alternative
Inputs needed	Brief manual to help navigate the Pathways Generator (link to the Pathways Generator Flyer.pdf) *Difficulty level of inputs needed: Medium difficulty*
Methodology	*Difficulty level of use of approach: Low difficulty*
Outputs	 *Difficulty level of preparing the outputs: Medium difficulty*
Contacts	Deltares Gaby Langendijk, Gaby.Langendijk@deltares.nl Sadie MacEvoy, Sadie.McEvoy@deltares.nl
More information	To learn more about adaptation pathways: https://pathways.deltares.nl

3.1.11 The Adaptation Pyramid

<table>
<tr><th>Overview</th><th>Information will be directly included on REACHOUT webpage</th></tr>
<tr><td>Name of tool</td><td>The Adaptation Pyramid</td></tr>
<tr><td>Tool description (overview)</td><td>The Adaptation Pyramid aims to help cities in setting ambitions on a balanced set of adaptation measures. The pyramid is a metaphor that resembles a climate-proof system which consists of reactive, incremental and transformative types of measures. It is a workshop approach where city representatives together discuss how to set a balanced ambition for the adaptation strategy for the city.</td></tr>
<tr><td>Main graphic</td><td>

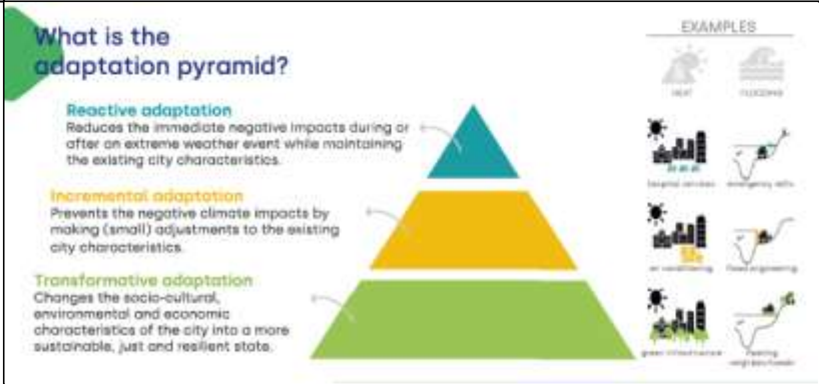


Figure 19: The Adaptation Pyramid

</td></tr>
<tr><td>Benefits of using the tool</td><td>With the adaptation pyramid, the aim is to visualise how they are moving towards a robust climate-proof system. The pyramid consists of three layers. From bottom to top they are: Transformative adaptation aiming to utilise the natural system and to address the root cause of climate related risks. The middle layer is about incremental adaptation often relying on technical measures. The remaining risk will be addressed through reactive adaptation which is related to emergency preparedness and acting in the event of extremes. A climate robust strategy will have a strong basis, relying less on incremental technological fixes.</td></tr>
<tr><td>Complementarity</td><td>The climate resilient development pathways and the pyramid can be used in a complementary way.</td></tr>
<tr><td>Complexity</td><td>Ranking: low</td></tr>
<tr><td>Link to tool webpage</td><td>https://climateadaptationservices.com/en/projecten/the-adaptation-pyramid/</td></tr>
<tr><td>User stories & hub experiences

(Decision processes for which City Hubs use the tools e.g. urban planning process, adaptation action plan, SECAP,…)</td><td>The first version of the Adaptation Pyramid concept was developed together with the water authorities of Delfland and Vallei & Veluwe in The Netherlands. The need to transition was being felt by the water authorities. The traditional (incremental) way of managing the water system would no longer hold against a background of climate change and rapid urbanization and development. Three cities have piloted the approach and it is being further implemented across three regions in the Netherlands.</td></tr>
<tr><td>[Examples – case studies]</td><td>https://climateadaptationservices.com/en/projecten/the-adaptation-pyramid/</td></tr>
</table>

Guidance	(will be included as pdf on the webpage)
Triple-A Toolkit	Ambition: (risk prioritization, identification of objectives)
Inputs needed	*Low difficulty = few inputs, non-expert can input*
Operation/Methodology	How does the tool work? Which method / approach is used? In three workshops (half day), concrete goals, targets and actions are being identified within the contexts of coping with heat, floods and droughts. This is being done for the three layers of the adaptation pyramid. Municipalities are asked to indicate the current as well as the preferred shape of the adaptation pyramid. The workshops trigger discussions about transformative change. In most cases cities indicate that incremental solutions have dominated over the past years. Only little effort has gone into transformative adaptation. Also reactive adaptation has not really developed. It is a qualitative workshop method that requires no to little preparation nor data inputs.
Outputs	The output is presented in tables that give a structured overview of identified goals, targets and actions for the three layers of the pyramid.
Contacts	Who are the contact persons for questions? hasse@climateadaptationservices.com eva@climateadaptationservices.com
References	To be added
Illustrations, graphics, screenshots	To be added

3.1.12 Climate Resilient Development Pathways (CRDPs)

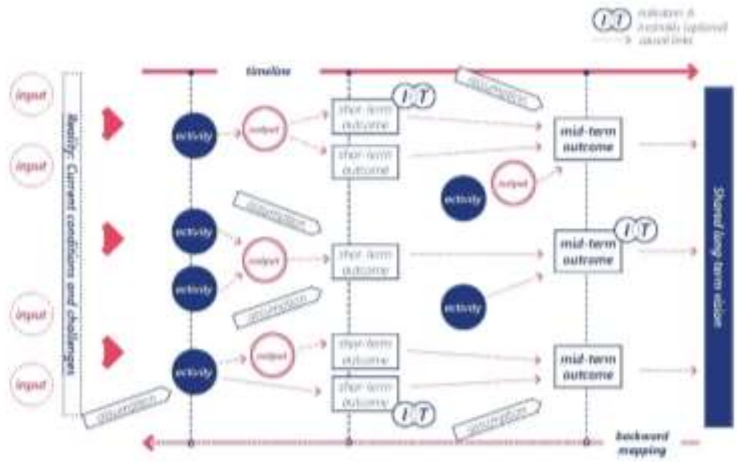
Overview	
Name of tool	Climate Resilient Development Pathways (CRDPs)
Tool description (overview)	Climate Resilient Development Pathways (CRDPs) aim to integrate adaptation, mitigation and sustainable development objectives into flexible pathways over time, while considering deep uncertainties regarding climate change, as well as other sources of uncertainty. CRDPs support integrated urban planning and implementation of climate action. CRDPs closely consider mitigation targets, and can be used for flood and heat impacts, as well as for a wide variety of development issues. The main target groups of the approach are decision makers and/or urban planners, although a wider

	engagement is recommended for different steps during the co-creation process of pathways. The climate resilient development pathways design process starts by envisioning multiple desirable futures and understanding the decision context and current policy objectives and actions, for adaptation, mitigation and development. Thereafter the synergies and trade-offs are assessed between the different climate actions, as well as tipping points are identified – meaning points in time when new action setting will be required. Consequently, alternative actions are co-developed for the future to stay on desirable pathways. The final outcome is a pathways map, as well as an implementation and monitoring plan.
Main graphic	N/A
Benefits of using the tool	• Integrated climate action planning, using a combined approach between adaptation, mitigation and sustainable development. • Designing pathways over time that can provide insights into the range of options to achieve resilient urban future(s). • Longer-term urban resilience planning under climate change and uncertainty (while also identifying near-term “no regret” actions). • Implementing integrated climate action. • It may support breaking silos within planning processes and municipalities.
Complementarity	• CRCTool may support defining adaptation actions, if CRDPs are developed at the sub-neighborhood scale. • FloodAdapt may support identifying flood risk areas and adaptation tipping points, and the tool can support testing different adaptation options under projected climate change. • SVI-Tool can help to identify areas with vulnerable groups to underpin the development of just pathways. • Other REACHOUT tools can provide data and information to support CRDP development (e.g. Heat Assessment Tool, Pluvial Flood Tool).
Complexity	This tool can operate on different levels of complexity: Low: Illustrative, qualitative pathways. Medium-to-high: Model/data-informed, quantitative pathways.
Link to tool webpage	No website, please contact: gaby.langendijk@deltares.nl
User stories & hub experiences (Decision processes for which City Hubs use the tools e.g. urban planning	• Cork, urban planning and implementation. • Potentially other REACHOUT cities (currently under discussion)

process, adaptation action plan, SECAP,…)	
[Examples – case studies]	See above, no concrete outcomes yet.
Guidance	To be added
Contacts	Gaby S. Langendijk, Deltares. Gaby.langendijk@deltares.nl
References	--
Illustrations, graphics, screenshots	

3.1.13 Theory of Change (ToC): Navigating transformation towards a desired vision

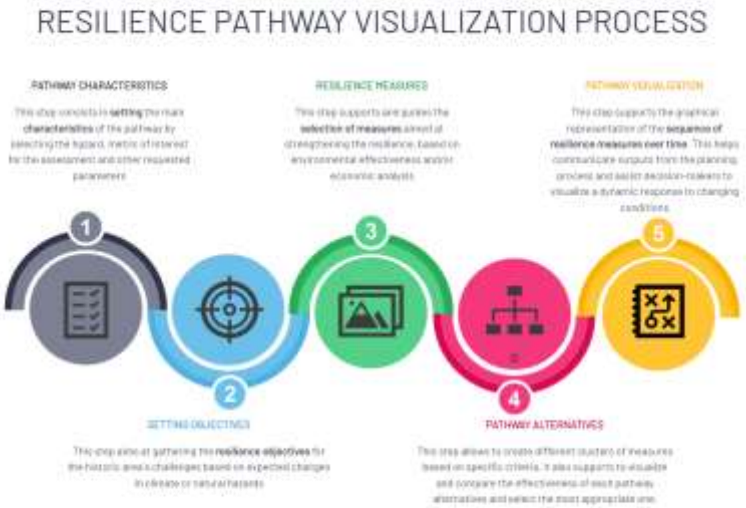
Overview	Information will be directly included on REACHOUT webpage
Name of tool	Theory of Change (ToC): Navigating transformation towards a desired vision
Tool description (overview)	General description of tool (in language for non-experts) The aim of a tool is to guide and support on the development of a Theory of Change (ToC) participatory workshop. ToC is essentially a comprehensive description and illustration of how and why a desired change is expected to happen in a particular context. In other words, ToC is a conceptual framework that outlines the causal pathways through which interventions are expected to bring about desired outcomes. The tool provides materials and guidelines for a collaborative work that constructs a ToC based on a shared vision considering the views from different stakeholders It guides participants in understanding current conditions, strategically planning activities, and identifying outputs and outcomes. The tool promotes inclusivity, ownership, and commitment among stakeholders, ensuring a logical and measurable framework that accommodates flexibility and iteration. It ultimately supports the documentation and communication of the developed theory of change.

Main graphic	 *Figure 20: Theory of change diagram*
Benefits of using the tool	A theory of change helps to identify solutions to effectively address the causes of problems that hinder progress (e.g. in climate adaptation) and guide decisions on which approach should be taken. Furthermore, creating a shared vision within a ToC fosters alignment and collaboration among stakeholders, enhancing the effectiveness of adaptation planning by ensuring collective understanding and commitment to common goals.
Complementarity	Are there any other REACHOUT tools (or other tools outside of REACHOUT) that this tool works well with? Analysis tools (e.g. climate impact diagrams, thermal assessment tool) may help to understand the problems and challenges that a city faces. Action tools, such as adaptation libraries *e.g*. RESIN AOL, that target to identify activities or adaptation solutions may be used to identify the activities to reach the change. ToC can also serve Adaptation or resilience pathways as an entry point. Pathways can help to prioritize and sequence the activities.
Complexity	*Ranking: Medium* ***Medium*** *= can be implemented by cities on their own with local knowledge and some knowledge of climate risks. However, developing a ToC for complex systems can be challenging, especially when stakeholders have limited experience or knowledge on the context.*
Link to tool webpage	PDF format (Coming soon)
User stories & hub experiences (Decision processes for which City Hubs use the tools e.g. urban planning process, adaptation action plan, SECAP,…)	To be added
[Examples – case studies]	[Link to the story maps of the city hubs]

Guidance	The tool is a PDF guidance to develop participatory workshops
Triple-A Toolkit	It is closely aligned with ambition setting, which involves defining ambitious and aspirational vision and goals for the future: • Developing a vision for a city often involves creating a clear narrative about the desired future state. The theory of change provides a structured framework to articulate this narrative, breaking down the vision into actionable steps.
Inputs needed	Developing a ToC typically requires the following inputs: 1. Contextual system understanding: • In-depth knowledge of the social, economic, and environmental context in which the initiative or plan operates. 2. Stakeholder engagement: • Involvement and participation of diverse stakeholders to capture various perspectives, sectoral knowledge and ensure inclusivity. 3. Evidence and research on the issue being addressed: • In climate change adaptation this can be vulnerability and risk assessment of the system, knowledge on the impacts of climate change etc. Medium, since there is a need for appropriate stakeholder engagement who have good knowledge on the system and evidence about the issue. *Medium = some data, some expertise*
Operation/Methodology	The method to develop a ToC involves several key tasks: Task 1: Identify long-term goal or vision and a reality of the current system Begin by clearly defining a specific, unambiguous long-term vision and current reality related to the socio-techno-ecological system. Analyze the current state thoroughly, considering existing conditions and challenges. This analysis serves as the starting point for establishing causal relationships, connecting the vision to outcomes, outputs, and activities systematically. Task 2: Develop a causal roadmap through outcomes and causal links Create a causal roadmap by identifying preconditions and outcomes that align chronologically toward the long-term goal. Use backward mapping to articulate causal links, ensuring the roadmap reflects a linear progression. This approach helps define realizable outcomes and maintains consistency throughout the pathway. Task 3: Operationalize outcomes through activities and outputs Translate established outcomes into clear activities and resulting outputs that contribute to achieving the expected outcomes. Activities represent actions that drive the intervention (or adaptation measures), while outputs are the tangible results or

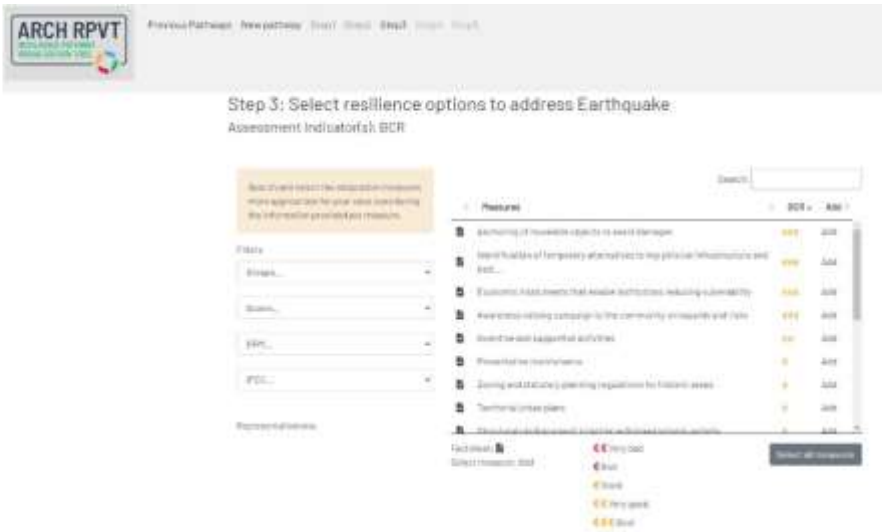
	products. This step helps identify change catalyzers and ensures alignment with the ToC. Task 4: Articulate assumptions Recognize and articulate key assumptions made by stakeholders regarding enabling conditions and contextual details. These assumptions represent trends or changes crucial for operationalizing outcomes. Grounded in evidence and research, assumptions serve as indicators to gauge the ToC's effectiveness and may prompt revisiting or modification if they prove inaccurate. An added value of the ToC lies in its ability to define indicators and thresholds for monitoring progress and adjusting strategies as needed. 2. What is the difficulty level of doing this step? Ranking: low, medium, high Medium, since there is a need for appropriate stakeholder engagement who have good knowledge on the system and evidence about the issue.
Outputs	The outputs of a ToC typically include: 1. Causal roadmap canvas (Figure 1): A visual representation illustrating the logical connections between the long-term vision, outcomes, outputs, activities, and assumptions. This diagram serves as a comprehensive and structured overview of the planned roadmap for achieving the desired change. 2. Shared Narrative (post-processing of ToC diagram): A shared understanding and narrative that articulates how the identified outcomes and activities contribute to the achievement of the long-term goal. This narrative is crucial for effective communication, collaboration among stakeholders and thus implementation of the ToC. *Medium = some expertise to postprocess and participation in the ToC*
Contacts	Who are the contact persons for questions? Saioa Zorita, TECNALIA, saioa.zorita@tecnalia.com Adriana Aguirre Such, TECNALIA, Adriana.aguirre@tecnalia.com Nieves Peña, TECNALIA, nieves.pena@tecnalia.com
References	
Illustrations, graphics, screenshots	

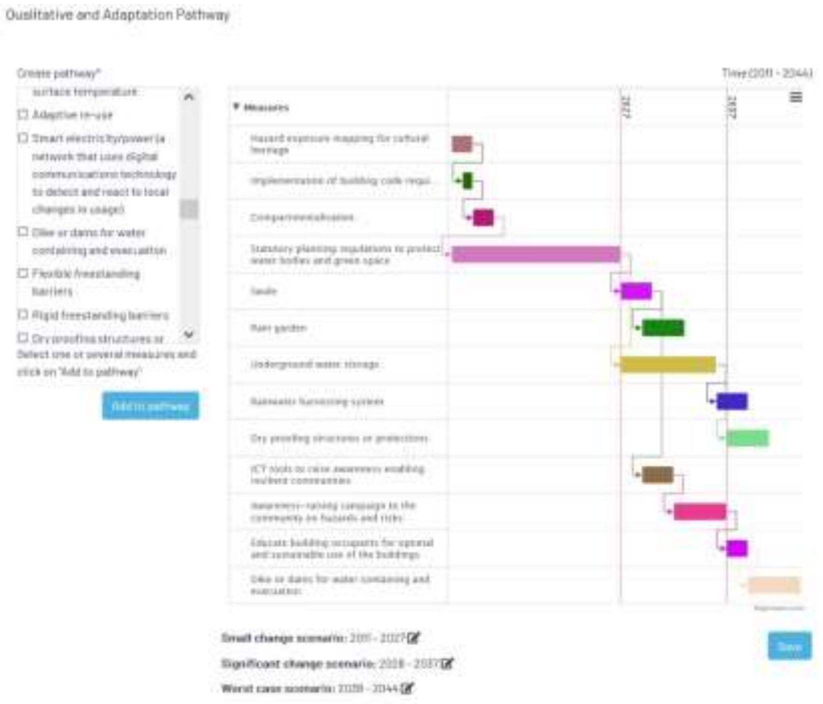
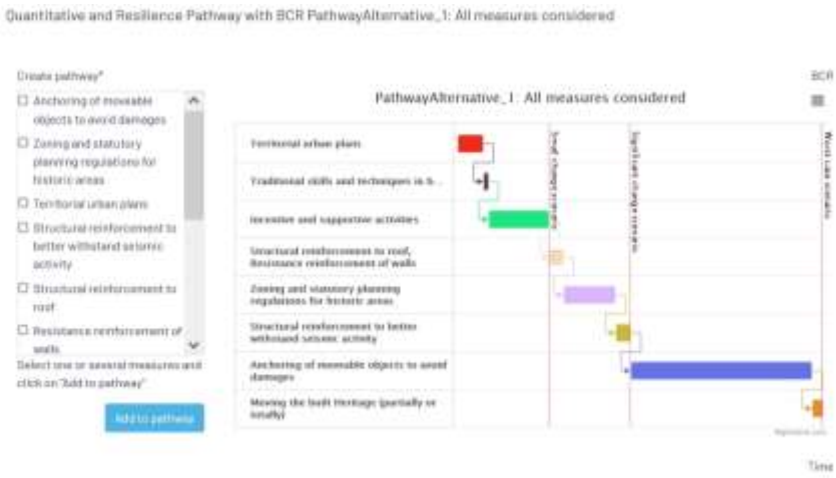
3.1.14 ARCH RPVT: Resilience Pathway Visualisation Tool

Overview	
Name of tool	ARCH RPVT: Resilience Pathway Visualisation Tool
Tool description (overview)	The ARCH Resilience Pathway Visualization Tool (ARCH RPVT) is an easy-to-use web-based tool to create and visualize resilience pathways (*). It provides a user-friendly graphical interface through which users interact to select, prioritize and sequence potential resilience measures over time that can be deployed as circumstances evolve. Measures can be selected and prioritized according to various performance metrics addressing mainly floods and heatwaves, but also earthquake and drought/water scarcity. The aim of the RPVT is to support the resilience pathway development to city administrators, heritage managers and/or decision makers in the context of historic, urban or agriculture areas. * A Resilience Pathway is a decision-making support approach, closely related to planning, that addresses both slow-onset climate change and natural disasters management. It is a roadmap - sequences of potential actions that can be implemented progressively as conditions evolve.
Main graphic	 *Figure 21 Steps followed to design a resilience pathway within the ARCH RPVT* Source: http://arch.tecnalia.com/index
Benefits of using the tool	Resilience Pathways, and thus ARCH RPVT, offers distinct advantages over conventional planning tools. Key benefits include: • The ability to accommodate various future scenarios, enhancing adaptability to climate change. • These pathways can rely on evidence ensuring robust planning and they facilitate the consideration of diverse actions and their optimal sequence to address challenges or risks. • Significantly, they minimize uncertainty by linking decision points to observed climate-related events rather than fixed timeframes. This approach provides flexibility and time for strategic planning, alleviating the immediate pressure of decision-making.
Complementarity	ARCH Resilience Assessment Dashboard (ARCH RAD) ARCH Resilience Measure Inventory (ARCH RMI) Climate resilience sustainable pathway

	Analysis tools
Complexity	*Ranking: medium-high* ***Medium** = can be implemented by cities on their own, if some basic knowledge of adaptation pathways* ***High** = Implementation only with support of tool developers/consultants*
Link to tool webpage	http://arch.tecnalia.com/index
User stories & hub experiences (Decision processes for which City Hubs use the tools e.g. urban planning process, adaptation action plan, SECAP,…)	To be added
[Examples – case studies]	[Link to the story maps of the city hubs]
Guidance	ARCH RPVT user guide: http://arch.tecnalia.com/static/file/D6.4_Annex_RPVT_User%20guide_21_07_2022.pdf The ARCH RPVT can be used in conjunction with the ARCH Resilience Pathway Handbook. (step-by-step methodology): https://savingculturalheritage.eu/fileadmin/user_upload/Deliverables/arch-handbook-update-23-v02.pdf
Triple-A Toolkit	Action: Identification, evaluation, prioritization and sequence of adaptation and disaster risk management measures considering climate change uncertainty for urban and agriculture areas with special focus on heritage.
Inputs needed	As part of the resilience pathway development, the user needs to understand the systems' context to set objectives or tipping points and vulnerability and risk. This needs to be done prior to the actual resilience pathway development. The ARCH Resilience Pathway Handbook can provides step by step guidance and provides some qualitative resources to understand the system and set the ground for a resilience pathway. On the other hand, The ARCH RPVT provides a list of 261 resilience measures with their environmental or economic performance, when available, that can be used for the pathway development. However, the ARCH Resilience Measure Inventory (ARCH RMI) gathers all the measures in an interactive tool that provides a more comprehensive overview of the resilience measures. *Medium = some data, some expertise*
Operation/Methodology	The ARCH RPVT guides users through a multi-step process (Figure 1) for designing pathways addressing climate change adaptation and disaster risk management. In Step 1, users set characteristics such as pathway name, description, and type of inventory (urban or agricultural heritage). Based on this, the ARCH RPVT pre-configures drop-down menus for hazard selection

	(e.g., flood, heat extremes, earthquake). Users then choose between adaptation or resilience strategies. In Step 2, users describe objectives (or tipping points) for adaptation or resilience in the historic area. Step 3 involves selecting resilience/adaptation measures, with the ARCH RPVT providing a list of measures tailored to the pathway characteristics. Users can filter measures based on environmental or economic performance, selecting those relevant to their pathway. Step 4 involves creating pathway alternatives. Users can manually select measures or use criteria for comparison, visualizing their performance through bar charts. The ARCH RPVT allows users to explore various pathways, benchmarking them against resilience goals. In Step 5, users sequence resilience measures over time and allocates measures to different scenarios, which can be linked to tipping points. The tool offers qualitative and quantitative representations based on environmental effectiveness or economic efficiency (BCR analysis). These visualizations assist in prioritizing measures and understanding what each pathway entails for implementation and it emphasizes that the implementation of the measures has a degree of uncertainty, depending on the evolution of climate change. For further information, please visit the user guide. *Medium = some expertise needed*
Outputs	The ARCH RPVT is conceived for both climate change adaptation and disaster risk management with focus on (1) heritage building & urban settings as well as (2) cultural heritage landscapes with focus on agricultural heritage. It is conceptualised to support and guide practitioners: - to gather evidence-based information about resilience measures identified in the ARCH RMI or RPVT (Figure 22); - to select and compare measures based on environmental effectiveness and/or economic analysis (Figure 22); - to create and benchmark different alternatives (cluster of measures) based on different performance metrics; - to build resilience pathways (roadmaps) by sequencing the potential measures over time considering different scenarios or changing circumstances (Figure 23 & Figure 24); - to communicate and assist decision-makers to visualize a dynamic response to changing conditions (Figure 23 & Figure 24). These outcomes may be used:

	- to understand which pathway may be more efficient to target our goals of resilience; - to support awareness raising and capacity-building; - to communicate and assist decision-makers to visualize a progressive and dynamic response to changing conditions; - to support SECAP development in the framework of the EU Covenant of Mayors  *Figure 22 The ARCH RPVT includes semi-quantitative performance information, in this case the Benefit-Cost Ration (BCR) of resilience measures.*

	 *Figure 23 Qualitative adaptation pathway visualization example for pluvial flooding hazard*  *Figure 24 Quantitative resilience pathway (pre-disaster phase) visualization example based on economic performance of measures* *Low = may not need postprocessing, but some adjustments to policy process*
Contacts	Saioa Zorita, TECNALIA, saioa.zorita@tecnalia.com Nieves Peña, TECNALIA, nieves.pena@tecnalia.com
References	
Illustrations, graphics, screenshots	

3.2 Global and EU level climate service tools for the financial sector

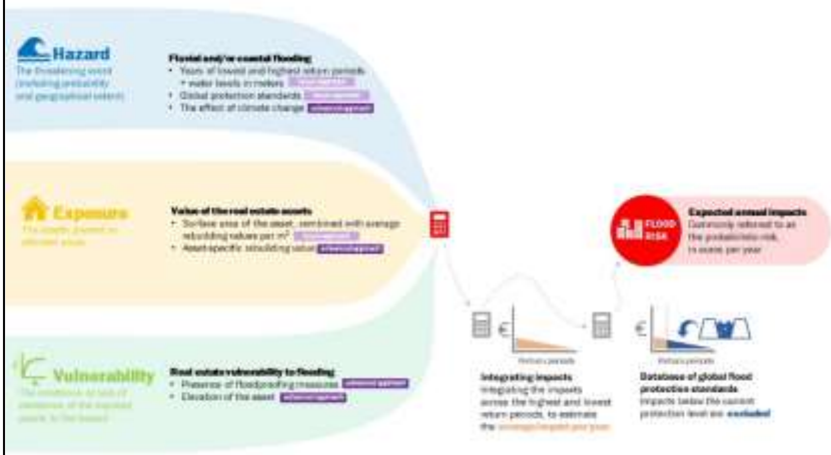
3.2.1 Dynamic Integrated Flood Insurance (DIFI) model

Overview	
Name of tool	Dynamic Integrated Flood Insurance (DIFI) model
Tool description (overview)	The DIFI model offers insight in the development of flood insurance premiums, unaffordability and demand for coverage under different flood insurance systems. The model uses climatic and socioeconomic input data from the flood model GLOFRIS. Results show the development of the insurability of flood damage across Europe and what action could be taken to enhance the sustainability of flood insurance markets to climate change. The target group of this tool consists of policy makers, insurance companies and real estate investors.
Main graphic	 *Figure 25: Development of unaffordability of insurance between 2010-2050 and 2010-2080.* Source: [1]
Benefits of using the tool	The tool offers insight in the insurability of flood risk in Europe. Moreover, the model can be extended to assess the reasons for a potential flood insurance gap: the level of uninsured flood risk. For example, more certainty of government aid after a flood event will reduce flood insurance demand. Outcomes may help policy makers in the stimulation of flood insurance uptake or the implementation of individual flood damage mitigation measures.
Complementarity	Complementary to the GLOFRIS tool from VU-IVM
Complexity	There is some expertise on climate assessments required. *Overall level of complexity: Level 2 (customized approach)*
Link to tool webpage	N/A
User stories & hub experiences	The Amsterdam city hub (APG) may benefit from the use of the DIFI tool to distinguish different possibilities for flood

	insurance based on their real estate investment portfolio and this may guide their investment decisions.
[Examples – case studies]	
Guidance	
Triple-A Toolkit	The tool can be used in the following Triple-A phase: **Analysis phase**: (risk & vulnerability, impact assessments) • identification of socio-economic tipping points for insurance uptake under climate change; • insight in the role of the government in crowding out insurance uptake; • evaluation of insurance market reforms that can improve the capacity of insurance to deal with climate change. **Action phase**: Outcomes may help policy makers: • for stimulation of flood insurance uptake; • to implement flood damage mitigation measures.
Inputs needed	• Input from the GLOFRIS model (also in the REACHOUT tool package) (medium difficulty) • Climate and socio-economic scenarios (RCP-SSP) up to 2080. (low difficulty) • Insurance structures in Europe (low difficulty) *Difficulty level of inputs needed: Low – Medium difficulty*
Methodology	The DIFI models matches three different modules and two types of additional input data. The first module is the flood risk module, which uses input data from GLOFRIS (REACHOUT tool), which gives expected annual damages for high-risk areas. Various climate (RCP) and socio-economic scenarios (SSP) are used for future projections up to 2080. The second module is the insurance sector module, where insurance premiums are calculated for different insurance systems. The final module is the consumer behaviour module, where the affordability of insurance premiums depends on income. [2] *Difficulty level of use of approach: High difficulty*
Outputs	The output of the model consists of calculated flood insurance premiums, projections of the unaffordability of flood insurance premiums. An individual within the model chooses whether they want to insurance and to what extent individual risk reduction measures are incentivized. The individual attempts to maximize their utility within the model, given financial constraints and expected insurance outcomes. This way, the uptake of insurance per region can also be calculated. Finally, the degree of incentivized flood risk reduction on the household level can be calculated. This may help stimulating individual behaviour for flood damage reduction. The format of the outputs is in maps per NUTS2 region that show the insurance uptake within these regions.

	Difficulty level of preparing the outputs: Medium difficulty
Contacts	VU-IVM Thijs Endendijk; t.endendijk@vu.nl
References	[1] Tesselaar, M., Botzen, W. W., Haer, T., Hudson, P., Tiggeloven, T., & Aerts, J. C. (2020). Regional inequalities in flood insurance affordability and uptake under climate change. *Sustainability*, *12*(20), 8734. [2] Tesselaar, M., Botzen, W. W., Robinson, P. J., Aerts, J. C., Zhou, F., (2022). Charity hazard and the flood insurance protection gap: An EU scale assessment under climate change, Ecological Economics, Volume 193, 2022, 107289, ISSN 0921-8009, https://doi.org/10.1016/j.ecolecon.2021.107289.

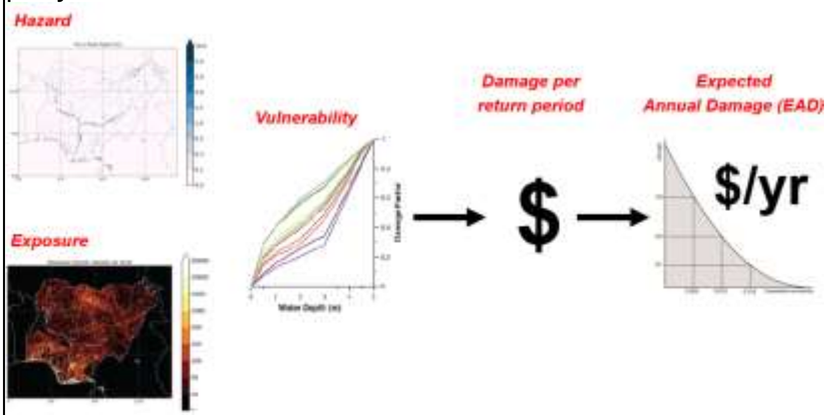
3.2.2 Real Estate Asset Climate Testing (REACT) tool

Overview	
Name of tool	Real Estate Asset Climate Testing (REACT) Tool
Tool description (overview)	Climate change and its associated risks, such as flooding, require assessing potential impacts on real estate assets to avoid depreciation in value. Following the implementation of the EU Taxonomy, EU regulations will mandate reporting on physical climate risks, emphasizing the need for transparency, openness, and standardization in physical climate risk assessments. The Real Estate Asset Climate Testing (REACT) Tool calculates Expected Annual Damage (EAD) (i.e., flood risk) for individual assets and portfolios, using EU-level open data in a simplified way. This tool serves as a screening process for real estate practitioners to assess flood risk in their EU-level portfolios, enabling informed decisions to tackle climate change-induced risks. Serving as an initial step for assessing the physical flood risk of assets, it does not constitute a comprehensive risk analysis. This typically necessitates more tailored flood risk models and input data (e.g., de Moel et al., 2014; Al Assi et al., 2023).
Main graphic	 *Figure 26: How the REACT tool calculates flood risk* Source: https://zenodo.org/doi/10.5281/zenodo.8333491
Benefits of using the tool	The aim of this freely available open-access tool is to enable data analysts supporting real estate owners, managers, and investors to conduct simplified risk assessments for individual assets and portfolios. Utilizing publicly accessible EU-level climate data and maintaining full transparency regarding the underlying methodologies, the goal is to enhance the comparability and reproducibility of the resulting risk assessments. The tool operates on an open approach, allowing asset owners to refine, compare, and integrate results as needed.
Complementarity	The tool is complementary with the FLOPROS database, which is an evolving global database of flood protection standards. Including flood protection standards gives a more accurate representation of flood risk.

Complexity	The objective of the tool is to offer simple, open, and transparent insights for real estate managers and policymakers to evaluate various types of flood risks (including coastal, riverine, and pluvial) for their assets. The tool is designed for use by data analysts with some Geographic Information System (GIS) knowledge, although extensive GIS or flood expertise is not necessary. *Overall level of complexity: Level 1 (Ready-to-use light approach)*
Link to tool webpage	A link to the REACT tool can be found here.
User stories & hub experiences	A simplified version named REACT tool has been applied for the Amsterdam city hub (APG) and real estate investor AEW. The tool functions well as an early scan/overview of pluvial and riverine flood risk, although some background GIS knowledge is required.
[Examples – case studies]	• In a recent application of the REACT tool, APG conducted a flood risk assessment for a random sample of European real estate assets. The analysis utilized open-source flood and regional protection data as recommended in the REACT tool technical documentation. • The analysis revealed intriguing nuances, highlighting significant shifts in vulnerability across specific regions and notable divergences among future time periods and scenarios. • The findings indicate a positive correlation between higher flood protection standards and a decrease in flood risk. Countries with robust protection standards exhibit greater resilience to flood hazards. • These results emphasize the importance of ongoing monitoring and adaptation to navigate the evolving landscape of climate-related risks. The REACT tool contributes valuable insights to the broader effort of enhancing climate risk assessments within the real estate sector.
Guidance	
Triple-A Toolkit	The tool can be used in the following Triple-A phases: • **Analysis phase** to identify areas with higher flood risk where action is required. • **Action phase** to assess the impact of several adaptation strategies, assisting the decision-making process.
Inputs needed	- Hazard: inundation maps (e.g. Dottori et al., 2022)), preferably on a high resolution. The tool itself gives some recommendations for open-source hazard maps (Difficulty: medium) - Exposure: value at risk of flooding. This can be the rebuilding value of specific building types within the flood prone area. It is possible to input either the surface area of the building or an absolute rebuilding value (Difficulty: low)

<table>
<tr><td></td><td>- Vulnerability: the relationship between inundation depth and flood impacts, already included. Another option in the advance version is to account for the impact of specific adaptation strategies. For example, the damage-reducing potential of building level strategies or the protection standards for large-scale protection. (Difficulty: low)

Difficulty level of inputs needed: Medium difficulty</td></tr>
<tr><td>Methodology</td><td>The REACT tool combines flood hazard, exposure and vulnerability to determine flood risk. First, hazard is the probability of flooding and the impacts that come with certain probabilities. Exposure refers to the value at risk of flooding, typically determined as the value of buildings per m2 in an area or the average value of a specific land use category. Finally, vulnerability means the sensitivity of buildings or land use types to flooding. The tool scans for each grid cell the inundation depth, and calculates the percentage of damage caused by this water level, to match that with the asset's actual value. Summing up all these grid cells will give the expected direct damage per return period. Adding all return periods will give the expected annual damage (EAD) of flooding. This is denoted in € per year.



The first step is to load in all the input data as described before (difficulty: medium). The next step is to run the model to determine flood risk under current adaptation strategies. The inclusion of different potential adaptation strategies will require the adjustment of input data (difficulty: medium).

Difficulty level of use of approach: medium difficulty</td></tr>
<tr><td>Outputs</td><td>The REACT tool estimates expected annual damage (EAD) for flooding (in euro/year) for individual assets making use of a simplified risk calculation. It offers advanced options to incorporate asset-specific values, adaptation measures, and the influence of climate change on risk. Users are encouraged to customize the tool to their unique use cases, facilitated by its simple and open setup in Excel.

Being primarily designed for screening purposes, the tool provides a preliminary estimate of flood risk for assets or</td></tr>
</table>

	locations within a portfolio. However, for asset-specific decisions, a more detailed and comprehensive risk analysis using tailored local input would be essential. *Difficulty level of preparing the outputs: Low difficulty*
Contacts	Thijs Endendijk – VU-IVM – t.endendijk@vu.nl
References	[1] Ward, P., Jongman, B., Aerts, J. et al. A global framework for future costs and benefits of river-flood protection in urban areas. Nature Clim Change 7, 642–646 (2017). https://doi.org/10.1038/nclimate3350

4 Summary and next steps

The tools can be used as standalone products or since many of them have crossovers, can be used in complementarity with others. We have created an overview to highlight the main features of the tools. Table 2 demonstrates that many of the tools are based on a customized approach, meaning that tool's design and use need some technical expertise for specific adjustments.

Table 2 Complexity and requirements for tool operation

Tool name	Overall complexity	Notes (Explaining the complexity level rating.)
Pluvial flood hazard and risk assessment in urban areas (C3S)	Level 2 (customized approach)	The complexity is variable. Low if user accesses the existing model platform, Medium to high if the user runs the underpinning model
Assessment of Risk management capabilities	Level 1 (Ready to use light approach)	Application of the tool requires extensive knowledge of urban planning instruments, policy priorities and capabilities.
Climate Resilient City Tool (CRCTool)	Level 2 (customized approach)	The configuration must be done by trained users and has medium complexity. Creating a new version of the tool based on the source code has high complexity
FloodAdapt tool	Level 2 (customized approach)	The city needs data on topography, bathymetry and building assets and their potential maximum damage and flood damage functions for the initial set up of the tool in a new city.
Crowdsource module for climate hazard mapping	Level 2 (customized approach)	Setting up the crowd sourcing tool is not difficult, but it requires a software download and basic ICT skills.
Climate impact diagrams	Level 1 (Ready to use light approach)	The impact diagrams workshop can be organised by cities on their own, but for a more thorough approach, it is necessary to bring climate science expertise to the workshop (e.g., from the national meteorological service).
Social Vulnerability Tool	Level 2 (customized approach)	Tool implementation only with support of tool developers or consultants
Thermal Assessment Tool	Level 1 (Ready to use light approach)	Low complexity to use standard online version based on C3S publicly available data. High complexity for setting up a tailored version with local data and local established heatwave definition thresholds.
Climate stories	Level 1 (Ready to use light approach)	Can be low or high depending on complexity and ambition of story and quality of output desired.

Tool name	Overall complexity	Notes (Explaining the complexity level rating.)
Adaptation pathway generator tool	Level 1 (Ready to use light approach)	The tool can be implemented by cities on their own, if some basic knowledge of climate adaptation is available.
The Adaptation Pyramid	Level 1 (Ready to use light approach)	The tool can be implemented by cities on their own.
Climate Resilient Development Pathways (CRDPs)	Level 1 (Ready to use light approach)	This tool can operate on different levels of complexity: Low: Illustrative, qualitative pathways. Medium-to-high: Model/data-informed, quantitative pathways.
Theory of Change (ToC)	Level 2 (customized approach)	Can be implemented by cities on their own with local knowledge and some knowledge of climate risks. However, developing a ToC for complex systems can be challenging, especially when stakeholders have limited experience or knowledge on the context.
ARCH RPVT: Resilience Pathway Visualisation Tool	Level 2 (customized approach)	Can be can medium or high, can be implemented by cities on their own, if users have some basic knowledge of adaptation pathways or implementation is possible with support of tool developers/consultants
Dynamic Integrated Flood Insurance (DIFI) model	Level 2 (customized approach)	There is some expertise on climate assessments required.
REACT	Level 1 (Ready to use light approach)	The tool can be implemented by cities on their own, if some basic knowledge of climate data/adaptation information is available, e.g. basic GIS knoweldge.

During the upcoming and last development cycle of REACHOUT, the tools presented above will be developed further. REACHOUT team members are also in various stages of conceptualisation and development of additional tools. These tools will be further explored in the upcoming production cycles and reported on in D3.7. Furthermore, it is planned to prepare two short videos to present the tools at the REACHOUT Triple-A Toolkit.

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