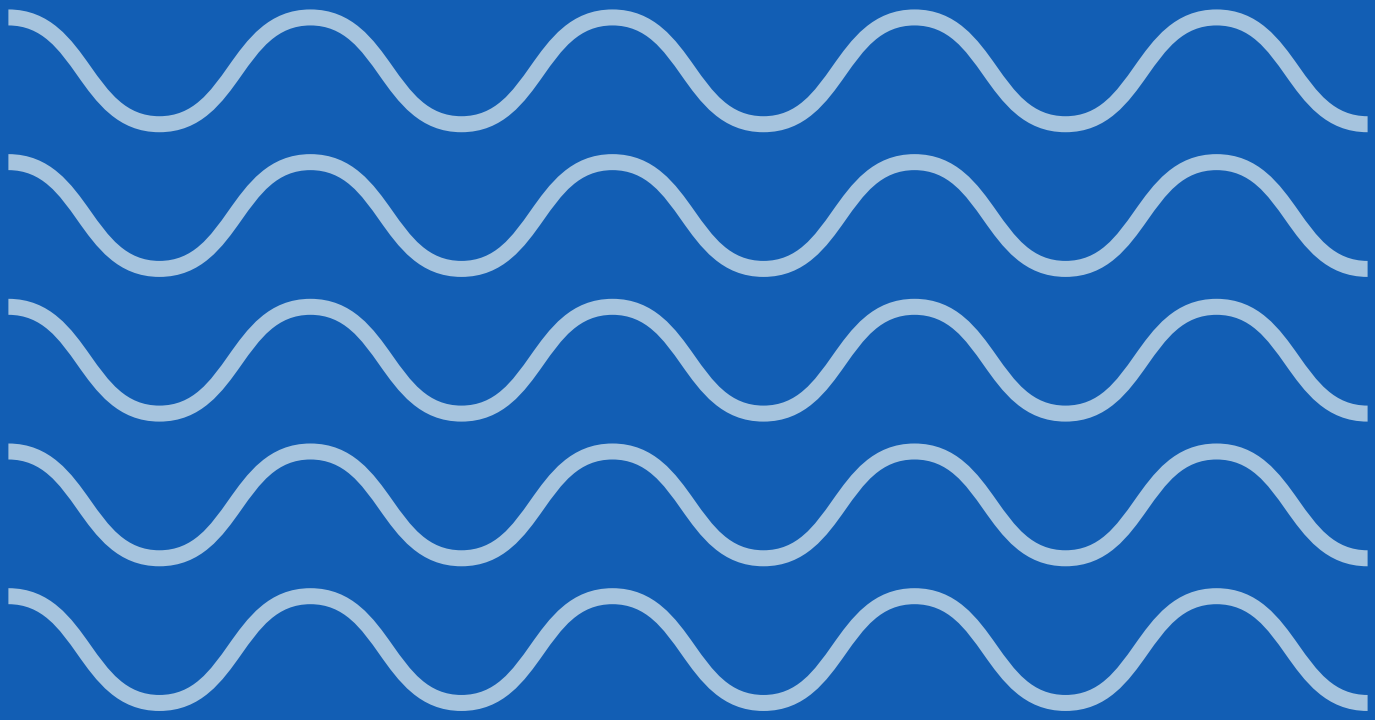
BINGO
a better future under
CLIMATE CHANGE

THE BINGO E-BOOK



Contributions for a better future under CLIMATE CHANGE

September 2019

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Preface

At the outset of BINGO, we understood that implementing such an ambitious project successfully would not be an easy task, despite the key and innovative challenges we put forward in the Proposal, the enthusiastic green light given by the EU´s Panel evaluation and the confidence on the exceptional quality of our team – the **BINGOlians!**

We also expected to place a lot of dedication and personal time in BINGO, so I asked to be released from my position of Head of the Hydraulics & Environment Department to ensure this commitment fully in hands together with Ana Estela. Today, looking back on BINGO's four years of hard work, we feel that we took the right decision.

Throughout the project, a lot of time was spent managing the works and the timeline, as well as trying to challenge the concepts pre-established by all different team members, reconciling the various perspectives into a result that enhanced BINGO's international impact and validity, contributing to better knowledge integration and outreach on adaptation to Climate Change regarding water.

The wide range of professional, personal and cultural backgrounds of our team, as well as the BINGO family spirit happily built and strengthened along the journey, allowed us to consolidate a robust and diverse view of the impacts of Climate Change on several water-related sectors. All of us, including researchers, decision makers, stakeholders and members of the society had to challenge the paradigms, or boxes, in which we framed our thoughts to make the BINGO's outcomes more comprehensive and widely applicable.

We all wish our work can continue to contribute to future advances and to support further developments upon the path left by BINGO. We hope our guidelines inspire you and that our outcomes can be useful for your work – then we will have achieved our goal!

And finally, the journey is always more important than the end product and in our journey we gained in knowledge sharing, enthusiasm, respect and friendship.
Let us hope that you take this journey with us, the BINGO team, and all together we can build a better water future under Climate Change.

The BINGO´s project Coordination,
Rafaela de Saldanha Matos
and Ana Estela Barbosa

Executive Summary

This e-book aims at presenting the experience, methodologies and results of the BINGO project. The material was prepared for all stakeholders involved in water management and water resources uses that are aware and concerned about the impacts of Climate Change; decision makers that must integrate adaptation to Climate Change to their agenda and also organisations/associations dealing with informing the public, and interested civil citizens in general.

BINGO was a 4-year (2015-2019) Horizon 2020 project that aimed at understanding the impacts of Climate Change on the water cycle in

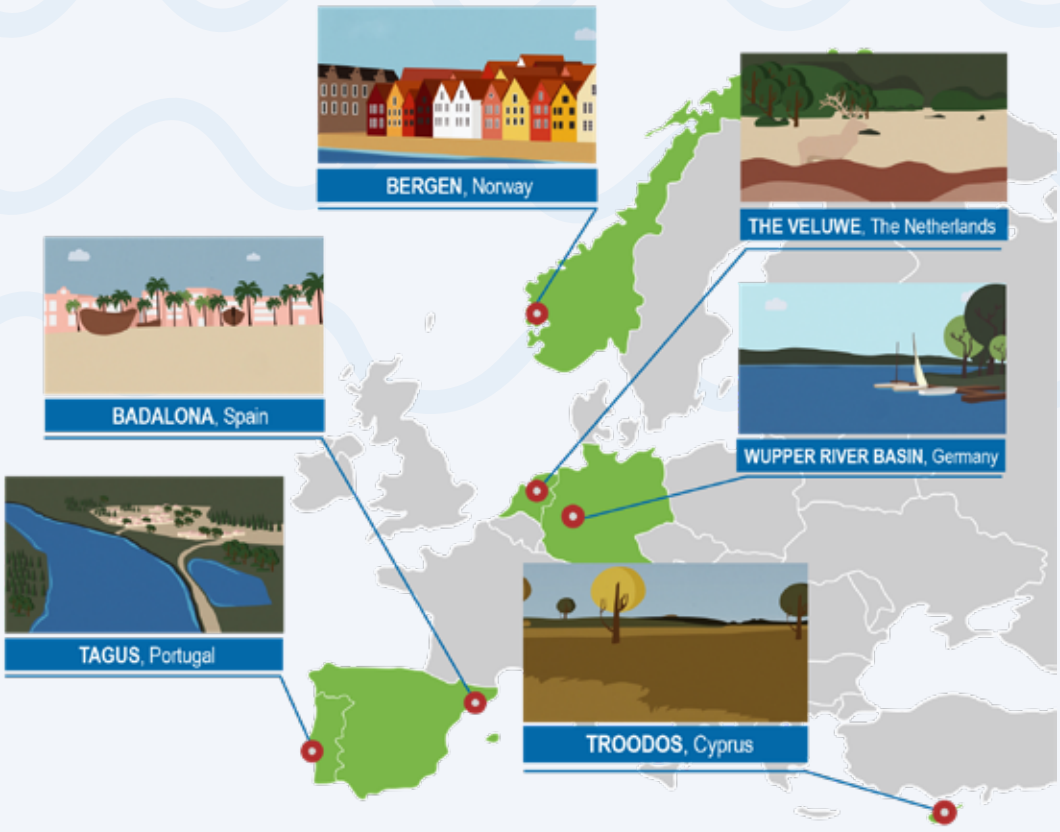


Figure 1

Executive Summary

6 research sites in Europe, with 10 year climate predictions, assessing the risks for socio-economic activities and providing adaptation solutions for stakeholders.
These six research sites represent challenges in terms of water management options and approaches and have been selected based on relevant criteria and covering a representative range of conditions. There is a large variability of situations that BINGO tackled, both from the climate scenarios and the water cycle changes perspectives.

The process of the work in BINGO followed the following methodology:

- Climate predictions and downscaling to extreme weather
- Integrated analysis of the water cycle
- Assessment of the impacts of extreme weather events
- Developing risk treatment and adaptation strategies for extreme weather events
- Ensuring Excellence and Actionable Research

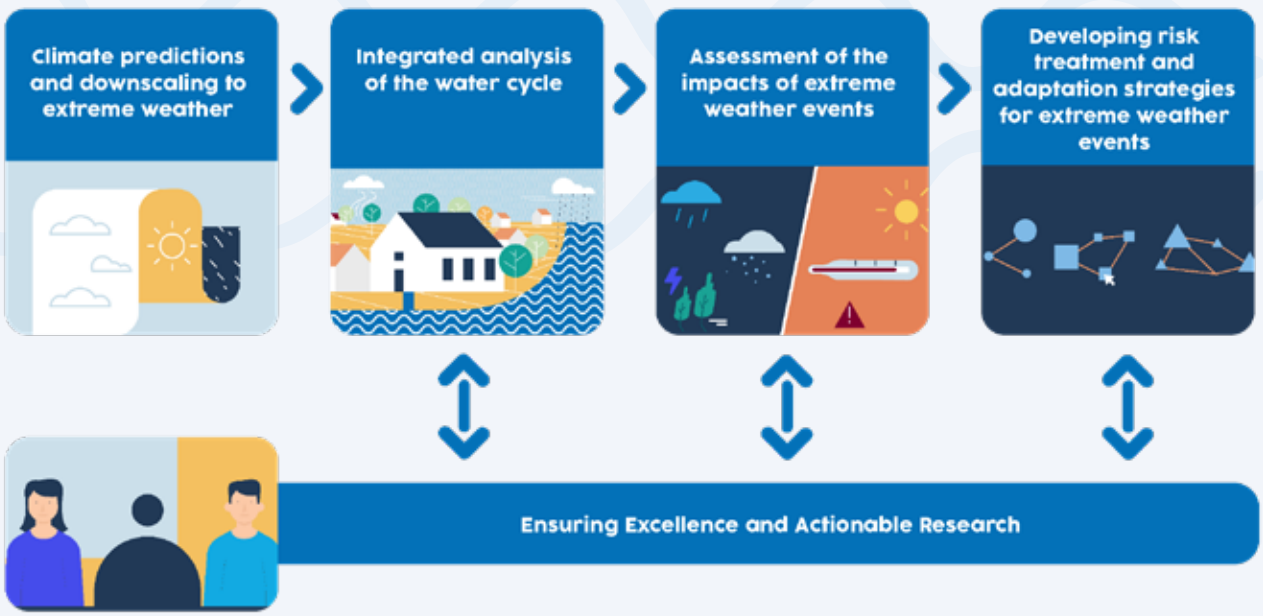


Figure 2

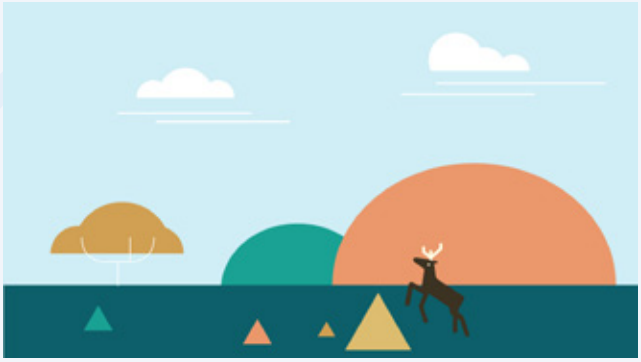
Executive Summary

The project developed innovative methodologies, transferrable to external stakeholders:

- Collaborative Management in Climate Change Adaptation
- Dynamical downscaling to 1 km scale – method, rainstorms
- Application of hydro models
- Performing risk assessment
- Prioritisation between adaptation measures
- Guidelines designed to create, feed and enhance “win-win” collaborations between researchers and stakeholders

Veluwe

- Making groundwater a more prominent topic in the overall management of the Veluwe and involving local stakeholders in different policy platforms
- More knowledge about effects of Climate Change on the groundwater system of the Veluwe
- Insight into the impact of possible adaptation measures



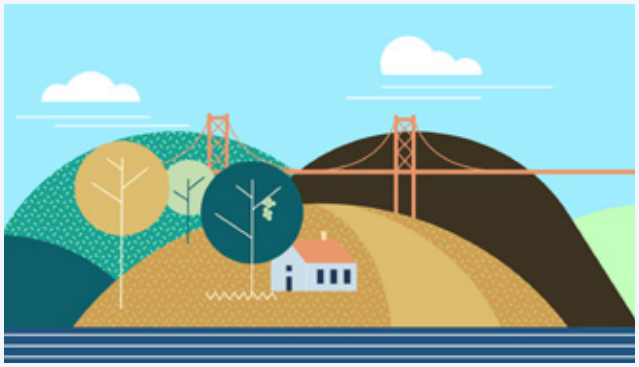
Executive Summary

Tagus

- Hydrological (surface and groundwater) and estuarine modelling to project flows and salt water contents based on decadal CC meteorological predictions
- Knowledge improvement on key risk factors and vulnerabilities of water dependent socio economic activities (public and agriculture water supply).
- Implementation of a comprehensive risk management approach for risk reduction concerning water sources for public supply and agriculture
- Testing adaptations plans to "next-decade" projections in public water supply
- Identification of requirements to improve water resources governance practices
- Development of a Tagus water resources management model to help in assisting decision making and CC adaptation

Wupper River Basin

- Relevant experience on how to handle climate data from circulation models
- For the interpretation of resulting discharge from decadal predictions, statistical parameters should be used for comparison instead of absolute quantities to avoid one-to-one correspondence
- Land use changes only for the next decade do not play a significant role on runoff generation Water use scenarios, on the other hand, proved to be most sensitive for the Größe Dhünn Reservoir - all decadal members reflected the same trend, indicating a slight diminishing of water availability for the next decade
- Soil measurements can be easily implemented (new communication techniques) and are very helpful to improve modelling



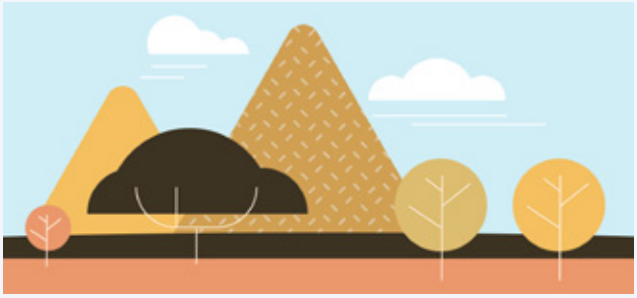
Executive Summary

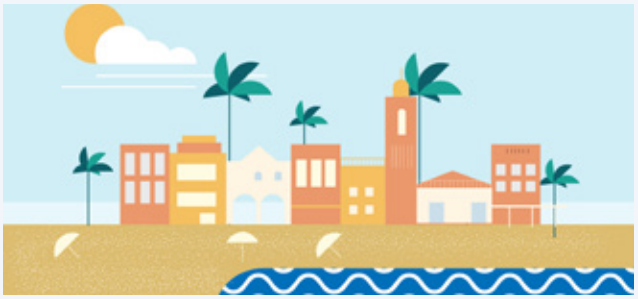
Troodos

- Successful Downscaling at 1x1km resolution of rainfall extreme events
- Successful use of high-resolution downscaled rainfall events in hydrological models
  - Model used for Flood Directive Implementation - Observed Rainfall data from the relevant Meteorological Stations
  - Model used in BINGO - 1×1 km high-resolution downscaled rainfall WP2
- One of the members of the ensemble set produced excellent results compared to the results of the model using observed rainfall data
- Calculation of flood flows of extreme future episodes under climate and land-use change conditions
- Understanding of the effectiveness of Tamassos Dam under various initial dam conditions scenarios
- Flood Maps

Badalona

- Innovative technological solutions supporting decision-making processes, such as:
  - 1D/2D coupled model for urban flooding impact assessment - Risk maps for pedestrians and vehicles in the event of flooding, which will be included in the current emergency protocols (civil protection)
  - Integrated sewer and marine modelling for CSOs impact assessment - Methodology for CSOs pollution estimation based on rain intensity
- Roadmap for an effective Climate Change adaptation: Consensual list of adaptation measures and Cost Benefit Analysis (CBA) for each of the alternatives, including cost of inaction.
- Engagement and active participation of multiple stakeholders in: Flood and CSO risk management processes and Climate Change adaptation and resilience of urban drainage system

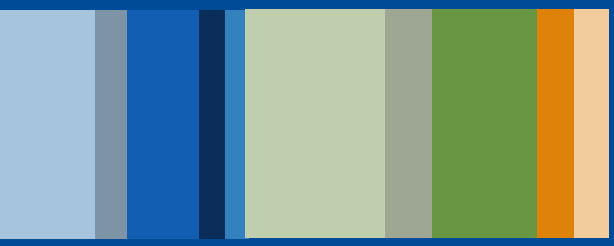




Executive Summary

Bergen

- Future climate projections for Bergen, both near- and long term, as well as planning and design tools
- Impacts on Combined Sewer Overflows (CSOs): Model development and identification of problematic CSOs
- Risk assessment: Frequency analysis and vulnerability analysis
- Adaptation measures and strategies: development of a digital platform for public involvement and decision support table for adaptation measures



1 INTRODUCTION

1 Introduction

Climate Change. Water scarcity. Floods. Droughts. Heavy rains. These words have increasingly punctuated our current dialogue in Europe – socially, academically, and politically. There are plenty of long-term concepts on how to face Climate Change. But how can decision-makers and end users face the intermediate challenges Climate Change brings? What is the right path and time scale to address today and be prepared to future climate scenarios?

The Horizon 2020 project BINGO: Bringing INnovation to onGOing water management - a better future under Climate Change (2015-2019) aimed at providing practical knowledge and tools to end users, water managers and decision and policy makers affected by Climate Change to enable them to better cope with all climate projections, including droughts and floods.

WHAT IS BINGO?

BINGO was a 4-year (2015-2019) Horizon 2020 project that aimed at understanding the impacts of Climate Change on the water cycle in 6 research sites in Europe, with 10 year climate predictions, assessing the risks for socio-economic activities and providing adaptation solutions for stakeholders.

WHAT CAN I LEARN FROM BINGO?

From BINGO you can learn methodologies that can support you to create:
Improved and downscaled climate predictions and projections of climate variables;
Integrated analysis of the impacts of Climate Change scenarios on the water cycle;
Improved dialogue towards collaboration between different actors, including decision makers;
Increased public awareness of the effects of Climate Change on floods and droughts;
More efficient management of water resources in Europe

Led by Laboratório Nacional de Engenharia Civil (LNEC, Portugal), the project involved 20 European Partners from six countries, including research and innovation centres, water authorities, water users and companies.

BINGO provided demand-driven solutions for specific climate related challenges, in particular for highly vulnerable water resources of strategic

1 Introduction

importance. It addressed average and extreme conditions of Climate Change scenarios in six areas across Europe, from North to South:

Figure 3

The The key outcomes of BINGO include:

- Improved and downscaled climate predictions and projections of climate variables;
- Integrated analysis of the impacts of Climate Change scenarios on the water cycle;
- Improved dialogue between different actors, including decision makers;
- Increased public awareness of the effects of Climate Change on floods and droughts;
- Development of knowledge and tools for a more efficient management of water resources in Europe.

This e-book is the culmination of 4 years of work from a large, multidisciplinary team covering different locations around Europe. Its objective is to compile, in an easy to read format, all the results produced by BINGO and inspire the readers to think about their approach to Climate Change, water, adaptation measures and collaboration. It is aimed at all the different actors involved in water-related activities which can be affected by Climate Change, from researchers, to decision makers, policy makers, technicians, and society at large. It covers sectors such as water supply, water management, urban drainage, coastal areas, civil protection, Climate Change adaptation, agriculture, irrigation and hydrology.

WHAT CAN I FIND IN THIS E-BOOK?

In this book you can find:
How we approached the challenge
Our results in each of the 6 research sites
The impacts of our work with the stakeholders and society
Guidelines for you to implement our innovative methodologies
Questions and answers
Some fun and games to be used by everyone (e.g.: school teachers)
And where to find more detailed information about all of our work

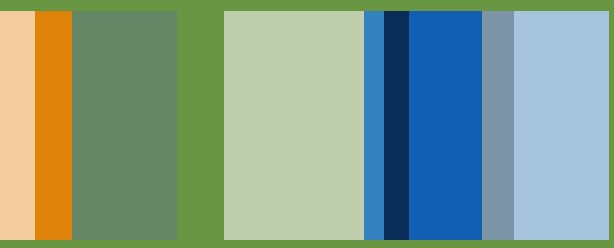
1 Introduction

This e-book has the following structure:

- How BINGO was born and its motivation: the ideas and needs which propelled the creation of /the project BINGO
- The process: how BINGO work was designed and developed, detailing each step of the BINGO methodology
- The case studies: the application of the BINGO methodology in each of the research sites, their results and the legacy
- How BINGO reached society: testimonials from stakeholders involved in project BINGO describing their experience and major take-aways
- Guidelines for methodologies: step by step guidance for the application of 6 methodologies produced by BINGO
- Q&A: a series of Q&As that aim to address the major questions about BINGO and its results
- Fun and games: materials produced by BINGO to disseminate the project in a fun and easy format, using art and addressing from children to seniors
- Resources: links to all the major information sources of BINGO

IS THIS E-BOOK FOR ME?

The short answer is: yes if you have a concern about Climate Change.
The long(er) answer is: Whether you are a researcher looking for data or methodologies, a policy-maker looking for support for decision-making, technical staff from water management, water supply, agriculture, trying to understand how to plan for the future in your activities, or even if you are none of these but you are worried about Climate Change impacts on water in your municipality, you should definitely go through our e-book and check how we did it in the BINGO project and how it worked out.



2 HOW BINGO WAS BORN AND ITS MOTIVATION

By Rafaela Matos, Ana Estela Barbosa,
David Schwesig and Sveinung Saegrov

2 How BINGO was born and its motivation

The origin of BINGO within ARC

The initial idea of BINGO was born inside ARC – Aqua Research Collaboration, a coalition of 6 applied research institutes with a proven excellence and leadership in water cycle research in Europe1. The mission of ARC is to catalyse the transition towards enhanced and more sustainable water cycle system services in Europe and the activity of its members is based on 3 main pillars, and one of these is to develop and execute implementation programmes for novel approaches and technologies in cooperation with utilities, water authorities and technology providers (action research).

In 2013, we were aware that H2020 would convey great opportunities of R&I cooperation in topics where the ARC members have strong competences. Moreover we had previous successful experiences in managing and working together, in rewarding collaborative research, in more than 10 EU projects during the past 15 years. Being conscious of the needs of our stakeholders with whom we closely worked with, we felt encouraged to search for a H2020 action line through which we could contribute with an innovative and challenging work plan, involving key actors in place.

The Horizon 2020 Societal Challenge 5 - Climate Action, Environment, Resource Efficiency and Raw Materials and the Call Water 2a – Work programme 2014 – Water cycle and future climate – water integrated approaches to water and Climate Change seemed to be the right theme fitting our vibrant common challenge. Specific researchers from 5 ARC members were established to start brainstorming and drafting the Project's Storyline. The very first step was accomplished!

Happily and timely, quite a number of ARC members were together in the final Conference of the Seventh Framework Program's project PREPARED - Enabling Change - late January 2014. In an inspiring environment and powerfully mobilised to set the scene for a winner BINGO proposal, we learned from several good discussions. We caught for the first time the Uncertainty Prayer and the concept of Actionable Research introduced by Paul Fleming, who later became chair of the BINGO Project Advisory Board. The concepts sounded very interesting, robust and innovative.

1 (1) LNEC, CETAQUA, IWW, KWR, NTNU and SINTEF – Despite of being CETAQUA the official member of the SUEZ group in ARC, the BINGO project was born with a strong participation of AQUATEC that became the contractual Partner in the H2020 BINGO consortium having CETAQUA as third-party.

2 How BINGO was born and its motivation

Uncertainty Prayer

**"Grant us....
The ability to reduce the uncertainties we can;
The willingness to work with the uncertainties we cannot;
And the scientific knowledge to know the difference"**

"Actionable science provides data, analyses, projections, or approaches that can support assessment or management of the risks and impacts of Climate Change. It is ideally co-produced by scientists and decision-makers working together, and creates rigorous, understandable, accessible and usable products to meet the needs of all

2 How BINGO was born and its motivation

BINGO's Proposal preparation - a fruitful collaboration

Within the following 10 days, we were able to mobilise and organise a face-to-face meeting in Lisbon, 10-11 February 2014, to outline the Proposal. It was well prepared and very productive. We developed the overall concept underpinning the project, the approach, and the possible research sites. We also agreed on the coordination as well as on the core people to be directly involved in the drafting efforts. At the end, we felt we have set the foundations for a great proposal, and our enthusiasm and expectations were high.

We spent the next 2 months working hard according to the plan to submit the BINGO project - stage 1, due by early April 2014. It included a synthesis of 10 pages focussing on the excellence and on the impact of the project. In late May 2014, we were happy to get the news that BINGO successfully passed to the Stage 2! The full Proposal had to be developed in the following 3 months. A thorough plan of actions and organisation for this period was previously prepared, and was checked and tuned upon the confirmation that BINGO would be in the final run. No summer holidays for the coordination.

The 2nd stage proposal development went effective and efficiently, in close cooperation with appointed team members from the 20 partners. Every week a virtual meeting took place between the coordination and the Work package leaders to check progress and to redefine issues in case of need. The project´s top key decisions were often preceded by a talk between the Coordination (Rafaela and Ana Estela, LNEC) and a "virtuous triangle" including Adriana Hulsman (KWR), Sveinung Saegrov (NTNU), David Schwesig (IWW).

2 How BINGO was born and its motivation

Project BINGO – the BINGO family and key success factors

The BINGO Kick-off meeting took place at LNEC, Lisbon, 9-10 July 2015. Around 250 invited people attended the Public Opening including high-level EC and EASME representatives, Ambassadors of the European countries with members involved in the BINGO´s consortium, decision-makers and a wide range of water professionals from administration, water authorities, water utilities and enterprises.

All together for the first time, we realised that we were building up a true BINGO´s family, a community of BINGOlians as later we were lovingly named.

At the end of a memorable and rewarding 5 years journey, there are a number of thoughts and "lessons learned" that we would like to share for future memory and, maybe, to inspire other leaders of future proposals and coordinators of R&I projects:

- All key decisions were jointly shared with the core group, even if, as coordinators, we never stepped out from our leadership duties. Although always valuing all competences and listening carefully and respectfully to the views from the team, the decisions were taken based on what was felt to be the best for the project route and in line with innovative concepts.
- A successful proposal and project implementation is not grounded solely on Scientific Excellence. There must be a coordination and team structure, with well-defined roles and responsibilities, as well as established communication flows. High emphasis must be placed on continuous, clear and ethical good communication, no matter if being written or oral, within the consortium or to outside recipients. Communication must not just "happen" but be a conscious process. This was key for BINGO, since the writing of the proposal, and throughout all activities that took place, including dissemination of the outcomes to other audiences than the research community. And, of course, to get support from native English speakers and get professionals to ensure illustrations and visual communication with high quality are vital.
- The establishment of a fair and balanced budget, in accordance with the workload distribution and the roles of each partner, is key for the successful evaluation of the project, for its implementation and last but not least, for the fairness among partners. The team feels

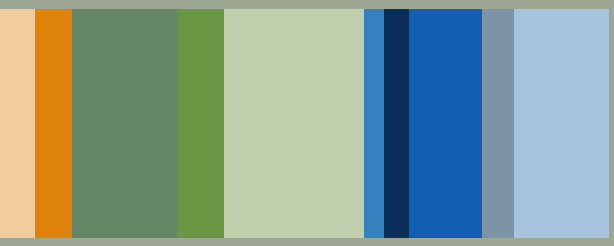
2 How BINGO was born and its motivation

motivated and rewarded when such procedures are in place. Only a well-established budget that is managed with transparency, respect and diplomacy allows ensuring the consortium continuous commitment to the work plan.

- During this 5-year journey, from the proposal preparation to the work activities, meetings' organisation, deliverables, dissemination activities, among others, organization and method were the privileged approaches. Timelines were drafted and all activities started in good time, allowing for a good integration among the overall project and also for time to discuss, revise and check the products. The coordination was always present and engaged in checking and supporting the effectiveness of the steps.

- Since the start of BINGO, we have used the joyful metaphor of the "playing orchestra" to illustrate how this joint joyful co-production has been. The orchestra has a leader, the maestro, as BINGO has had an established coordination. The maestro does not play or need to play the instruments. He or she knows the melody and how to conduct all the players, keeping them together and in tune. The maestro listens carefully to the musicians and their suggestions. The musicians do not conduct; they trust the maestro and follow him/she. And so has been with BINGO since the very first meeting - Lisbon, February 2014 - to the project´s final meeting - Lisbon, May 2019. We closed the BINGO's cycle but then our bonds will remain far beyond our joint experience.

We want to deeply thank our beloved BINGOlians and are very proud to share with all the dedicated team members the acknowledgment of "BRAVO, BRAVÍSSIMO" BINGO has received!

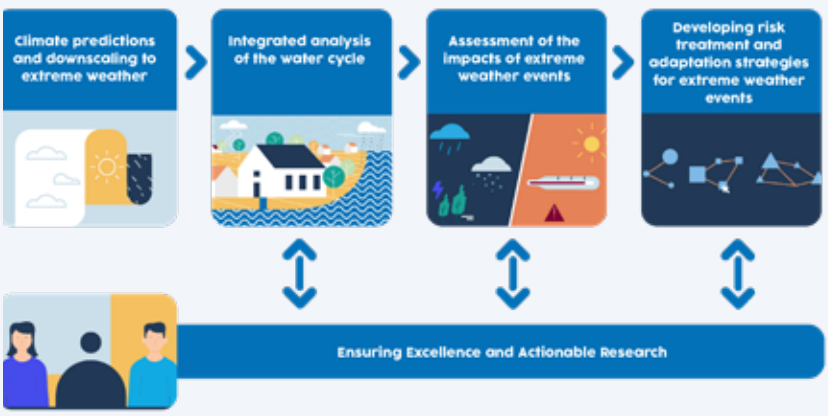


3 THE PROCESS

3 The process

BINGO aimed both at reducing the uncertainty of near-term climate predictions and developing response strategies that may help society to better manage the remaining uncertainty.

As such, BINGO provided to sectors using water resources demand-driven solutions for specific climate-related challenges in Europe that focus on different geographical scales and are usable by a diverse spectrum of end users. After developing decadal climate predictions with a specific focus on extreme events (droughts and floods), BINGO modelled the impacts of changing climate on the water cycle and water demands, and analysed how this could affect water availability and storage and the key sectors under scope. The assessment of risks and vulnerabilities allowed BINGO to establish adaptation measures considering the transferability of results. These measures were built taking into account the critical socio-economic factors, financing and policy contexts as well as scenarios of land use, urban pressures and water demands. All solutions were co-produced, tested and validated by key end users at the six research sites.



One of BINGO key outcomes, the Portfolio of adaptation measures incorporates the measures from BINGO 6 research sites plus a consistent list of possible adaptation measures that different end users can select to tackle their issue, or get inspired by them and establish their own solution.

The process of the work in BINGO followed the following methodology:

- Climate predictions and downscaling to extreme weather
- Integrated analysis of the water cycle
- Assessment of the impacts of extreme weather events
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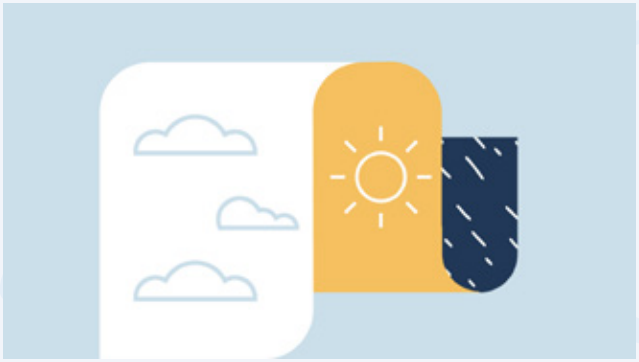
3 The process

3.1 Climate predictions and downscaling to extreme weather



To study short- and long-term changes in climate, BINGO used climate models to simulate the present climate, as well as ten-year predictions and future projections.

BINGO used pre-existing climate data – ERA-Interim reanalysis (1979-2015) and MiKlip decadal ensemble predictions (2015-2024) – as a basis for dynamical downscaling with a regional climate model, covering all research sites. This produced the higher spatial (12 km) and temporal (up to hourly) resolutions of the hydrological variables required by each research site for their own hydrological modelling activities.

The climate data produced in BINGO were disseminated via an online "Data Extraction and COnversion" tool (DECO) at the Freie Universität Berlin's Freva portal. The DECO tool, developed within BINGO, converts standardized climate data into formats specific for use with a selected hydrological model and also offers bias correction of the data.

BINGO focused particularly on the representation of extreme events, for which higher spatial resolution data offer considerable added value. In subsequent steps, kilometre-scale data were thus produced from the 12-km simulations by (i) further dynamically downscaling episodes with a higher chance of extreme precipitation, and (ii) developing a stochastic weather generator to inexpensively generate ensembles for each site.

The production of climate data within BINGO can be summarized in two main phases:

- Dynamical downscaling (12 km) and bias correction of (a) present climate and (b) decadal predictions (Section 3.1.1)
- High-resolution data production – e.g. for floods – via targeted dynamical downscaling and ensemble weather generators (Section 3.1.2)

3 The process

- Pre-existing EURO-CORDEX and MENA-CORDEX climate projections were also integrated into the project and spatial maps of intensity-duration-frequency curves were produced (Section 3.1.3).

3.1.1 Downscaling and bias correction of present climate and decadal predictions (12 km)

Dynamical downscaling in BINGO was performed with the COSMO-CLM regional climate model. Using ERA-Interim reanalysis as boundary forcing, a regionalization of the past and present climate (1979-2015) over Europe was produced at 12-km resolution, with a temporal resolution of 1- or 3-hours depending on the variable; the years 1989-2008 had already been simulated as part of the EURO-CORDEX project. At the same resolution, a ten-member ensemble of MiKlip decadal predictions (2015-2024) was produced over sub-regions of Europe encompassing the research sites. Due to its peripheral location, separate downscaling was performed for the Cypriot research site using a Cyprus-centred domain and the WRF regional model.

The 12-km simulations were bias corrected using the CDF-transform method and the best available reference data, for all sites except Cyprus (see this report http://www.projectbingo.eu/content/deliverables and this report http://www.projectbingo.eu/downloads/BINGO_Deliverable2.2.pdf). Users then had the option to receive data via DECO either with or without bias correction. The long record for the past and a decade ahead produced by BINGO served to determine average conditions as a baseline to define floods and droughts and to provide data for successive use in the integrated analysis phase.

3.1.2 High-resolution downscaling, with an emphasis on floods

The largest added value in very-high-resolution – i.e. on the order of 1 km – climate data is found in the representation of precipitation extremes. Such data are, however, computationally expensive to produce via dynamical downscaling. BINGO thus adopted a two-pronged approach to producing kilometre-scale climate data at affordable computational expense.

In the first approach, large-scale weather patterns with an elevated risk of extreme precipitation were identified from observations and reanalysis via a clustering algorithm, for each research site. Local-scale meteorological predictors of intense precipitation are also identified for each site. These factors were then combined in a classification algorithm (Meredith et al., 2018), which tests each day in the 12-km simulations for an enhanced risk of intense precipitation. Identified "potential extreme days" are then dynamically downscaled to 2.2 km resolution at hourly frequency. The resulting

3 The process

catalogue of kilometre-scale extremes at each site can be used for modelling of floods and combined sewer overflows, as well as stress-testing of hydraulic infrastructure, design situations and process-orientated case studies. Separately, for the site at Cyprus all high-resolution downscaling was to 1-km resolution and for the evaluation period the most intense events were selected directly from observations. In the second approach, a stochastic weather generator was produced for all interested sites (see this report http://www.projectbingo.eu/downloads/BINGO_Deliverable2.6.pdf and this report http://www.projectbingo.eu/downloads/BINGO_Deliverable2.8.pdf).
. This uses the 12-km simulations as boundary conditions to inexpensively produce large ensembles of BINGO-relevant hydrological variables at 1-km and hourly resolutions, which are consistent with the large-scale situation in the forcing data. Such large ensembles of continuous data would not be computationally feasible via dynamical downscaling.

3.1.3 Additional Products

While BINGO's main focus is decadal predictions, the EURO-CORDEX and MENA-CORDEX archives were also exploited to study climate projections up to 2100 under different climate scenarios (RCP2.6, RCP4.5 and RCP8.5). For inter-comparability, 12-km simulations which used the same global and regional models as in the decadal predictions were added to the DECO platform at daily resolution. Bias correction of these data was also provided.
Spatial maps of return-levels for extreme precipitation events for the research sites Badalona, Bergen, Tagus and Wupper – for various return-periods and event durations – were also computed. The return-levels were obtained based on a duration-dependent Generalized Extreme Value distribution with spatial covariates.

3.1.4 What was achieved?

- BINGO has produced a data exchange platform "DECO" for disseminating climate data in formats specific to individual hydrological models.
- We dynamically downscaled climate data between 1979 and 2015 (evaluation period), and from 2015-2024 (decadal predictions). Kilometre-scale simulations were also produced for extremal episodes via the development of a classification algorithm (Meredith et al., 2018), greatly reducing computational expense.
- Bias correction via the CDF-transform was applied to 12-km data.
- Using these data and observations, we developed (i) precipitation and weather generators, and (ii) spatial maps of rainfall return levels and intensity-duration-frequency curves for all research sites. A key result for end users is spatial maps of return periods.

3 The process

References
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3.2 Integrated analysis of the water cycle

Based on the data produced from the climate predictions, BINGO performed an integrated analysis of the water cycle for the 6 research sites. The analysis used a range of hydrologic, hydrodynamic and other hydro models, in accordante with the specific needs of each site and previous modelling work. Hydrologic extremes were carefully evaluated in the context of Climate Change. The analysis was done for the baseline situation (past and present) and for future scenarios that combine Climate Change with land use change.

3.2.1 Integrated assessment of the water cycle at the research sites

BINGO evaluated the state of water resources (surface and groundwater, quantity and quality) at all the six research sites and their sub-sites. This evaluation included a consistent characterization of the catchments and surface, groundwater, and estuarine water bodies, including land use and anthropogenic water abstractions, requiring measured data, results from previous research, literature and local knowledge.
In order to analyse the impact of future weather extremes and global change on water resources, hydrological, hydraulic and water quality models were employed. Some of the 20 models are operational and already calibrated and validated to the current climate for the sites of Wupper River (Germany), Bergen (Norway) and Veluwe (Netherlands). For other cases, models were set-up and calibrated/validated (e.g. Tagus River, Portugal). For a consistent evaluation of water resources, all models were first driven with downscaled present climate reanalysis data for current and past conditions (1985-2014).
At a second step, high-resolution climate input data for the time period 2014-2025 (and until 2100) was used at research sites where average evolution, and drought and flood occurrences were evaluated.
The above activities resulted in valuable outcomes including

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(i) improved forecasts of surface and groundwater water quantity and quality,

(ii) integrated water quantity/quality modelling, and

(iii) improved understanding of the dominant processes that translate meteorological extremes into hydrologic extremes.
The model performance at each site were evaluated and compared, providing insight into the shortcomings and benefits of model applications and allowed a step-by-step adjustment of the models in order to become innovative and reliable tools for local end users.

3.2.2 Field Investigations at the research sites

In order to improve the representation of floods and droughts, BINGO also focused on specific modules of the models. To improve process descriptions, it was necessary to investigate the relevant processes at the field sites. Due to the variety of dominant hydrological processes, different process algorithms were considered, such as:

- Actual and potential evapotranspiration processes were further investigated at the Dutch and Cypriot sites in order to analyse the effects of droughts on groundwater recharge and dynamics, runoff generation and vegetation patterns;
- At the German site, a sensor network of gauges and soil moisture sensors was implemented;
- At the Portuguese Tagus estuary continuous water level monitoring provided new data for model calibration;
- The Spanish partners implemented sensors in their sewer network.
- All field data were used to improve the process understanding, which drive the climatic impacts on the water balance.

3.2.3 Future land use scenarios at the research sites

Not only climate variability influences water resources; anthropogenic activities such as water abstractions and land use changes play a major role in this respect, as their impacts can increase or decrease hydrological extremes.
BINGO developed future land and water use scenarios at the research sites, based on socio-economic factors from the EU-FP6 project SCENES. These scenarios were based on socio-economic developments taking place in the recent past and possible future settings. Two contrasting SCENES scenarios have been chosen in order to provide a wide but still realistic range of possible futures:

- Economy First: High water use increases, strong population increases, land use intensification and;

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- Sustainability Eventually: Low water use and population increases, land use diversification.

Scenario data were collected in a combined top-down (SCENES) and bottom-up (local knowledge) approach and then pre-processed as input for the hydro models. The impacts strongly varied between the research sites and new knowledge was established and understanding of the local water cycles were established.

3.2.4 Water cycle at the research sites in different climate & land use

The final step consisted of merging the results from the integrated assessment of the water cycle, from field work, and from the future land use scenarios, allowing an overview of the water conditions under a combination of different possible scenarios, both of Climate Change (including extremes) and land use. The results of this task directly linked the occurrence of different climate (extremes) and land/water use patterns with water conditions, both in terms of quantity and quality, for local water resources managers.

What was achieved?

- Descriptions of the sites and the hydrological systems.
- 20 hydro models and modelling of last 30 years and the future 85 years.
- Improved our forecasts of the impacts of Climate Change on floods and droughts including learning of the local processes which drive these extremes.
- These integrative results helped to pave the way for the risk management process and for the risk management process, that followed.

3.3 Assessment of the impacts of extreme weather events

Based on the outputs coming from the climate predictions and the integrated analysis of the water cycle (hazard), BINGO assessed the risk associated with existing socio-economic activities, which results fed the risk treatment phase. The objective of this phase was the assessment of impacts of droughts and floods under climate change at the research sites, based on the risk assessment procedure from ISO 31000. It established indicators designed to

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identify scenarios that require the anticipation of strategic management measures, focusing on the impacts on human activities, namely: water and energy supply, public health, agriculture, tourism and urban activities.

Aligned with the Risk Management Principles (ISO 31000), risk assessment includes hazard identification, namely identification of risk sources and risk factors. The procedure also involves the selection of events for which risks are evaluated.

In BINGO, three steps of risk assessment were performed: risk identification, risk analysis and risk evaluation. The latter provided the decision on which risks need treatment, based on the comparison of results from risk analysis with previously set criteria. Prior to risk assessment, the context of risk analysis was established in close cooperation with the research sites' end users, providing the basis for risk evaluation. The assessment of the impacts of extreme weather events was also fed through workshops with stakeholders.

3.3.1 Establishment of the context for Risk Management Processes

The establishment of the context aimed to setup a common and clear understanding of all important factors at each research site, taking into consideration the end user's views for the choice of criteria and methodologies. The following activities were performed at each research site in cooperation with local stakeholders:

- Setting the scope (e.g., protection of public health and safety), extent (spatial scale) and specific focus of risk management.
- Compiling formal requirements (European, national, regional legislation or regulations, standards, codes of practices, etc.).
- Understanding the internal context, including anything that could influence the way in which risk would be managed (such as the roles, connections and perceptions of stakeholders and end users).
- Defining the external context for risk assessment (e.g. risk management activities; responsibilities and authorities; resources; methods and tools).
- Setting criteria for risk assessment and for the estimation and evaluation of risk, depending on specific conditions at each site.

3.3.2 Risk identification

Risk identification described the risks of extreme weather events at site. The relevant hazards were identified, as well as their risk sources

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(sources of uncertainty) and risk factors (related to vulnerabilities). The possible effect of climate change was assessed; scenarios and potential events were explored - Climate Change may affect existing hazards, or may lead to new ones, for each site.

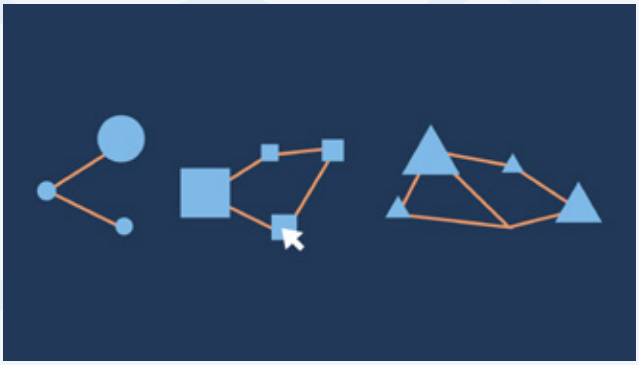
3.3.3 Risk analysis and evaluation

The risk analysis and evaluation assessed the likelihood and consequences for each event; estimated the level of risk for each event (based on criteria previously defined); evaluated risk for each event; and compared and reassessed estimated risks. To screen priority risks, a likelihood-consequence matrix was used.

What was achieved?

- Risks were evaluated considering each key sector and objective and then were reassessed integrating all key activities and objectives of analysis. Conflicting uses from different end users were identified.
- The main outputs were risk tolerance levels and vulnerabilities related to floods and droughts, the extent to which hazards associated with decadal climate predictions increase the risks for socioeconomic activities and people at each research site.
- Warning and action indicators were suggested in order to identify progression of Climate Change and the adequate time to implement certain adaptation measures.

3.4 Developing risk treatment and adaptation strategies for extreme weather events



One of the main goals of BINGO was to enable decision makers across Europe to develop adaptation strategies for extreme weather events, based on scientific analysis and through stakeholder cooperation.
Much work has already been done on climate adaptation, so as a first step, a portfolio of adaptation measures was compiled from previous studies (e.g. PREPARED and CARPATHIAN CC) and shared with the research sites. At the same time, a first round of workshops was held in which, at each research sites, Communities of Practices were formed.
Successful adaptation depends to a large extent to the policy and governance situation at the research sites. A first assessment of the policy and governance situation was obtained by a round of interviews with key stakeholders, policy makers and policy experts. These interviews

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were collected and analysed by the research partners and recommendations for improvement were made.
In the second round of workshops these recommendations were discussed with local stakeholders and a first selection of adaptation measures suitable to the local situation was made from the portfolio. In this workshop, the stakeholders also developed shared future visions of successful adaptation (dream scenario) and failed adaptation (nightmare scenario). These scenarios were useful to get a shared understanding of the impact of action and inaction. The reports of the first two rounds of interviews were compiled and analysed in a report.
With this first selection of measures, additional analyses can be made to support decision making on which measures to implement. A Multi-Criteria-Analysis (MCA) was conducted to evaluate options (such as measures) using a broad range of indicators, related to socio-economic or other (e.g. environmental) factors. In this way, the wider socio-economic effects and side effects of adaptation measures could be assessed to a broader extent than looking only at costs and the direct effect on risk reduction. In some sites, a more detailed Cost Benefit Analysis (CBA) was made.
To perform the MCA, stakeholders first selected relevant criteria to score the measures on and then scored the measures on these criteria. In this way, the measures could be compared to each other on their overall score and the score on specific criteria. The CBA provided a more detailed assessment of the cost of implementing the measures and the potential benefits of risk reduction (as well as side benefits) and the cost of inaction. Since cost and benefits of adaptation are often unequally distributed, a social justice analysis was performed to assess the effects of the adaptation measures on different groups in society and existing inequalities.

The selected measures were also analysed with regards to their governance needs. The framework that was used to assess the policy and governance situation was now applied to the individual measures. Local stakeholders were asked to identify what was needed to implement the measures (such as knowledge, administrative resources, legal resources, communication etc.) and whether or not these needs were sufficiently met at the research sites. Based on this analysis, recommendations were made with regard to the implementation of the different measures and overall improvement of the policy and governance situation.
The work in BINGO was conducted at six research sites, and the question is to what extent the knowledge developed in BINGO is transferable to other sites as well. Therefore we made an analysis of the types of results developed in BINGO and the extent to which this

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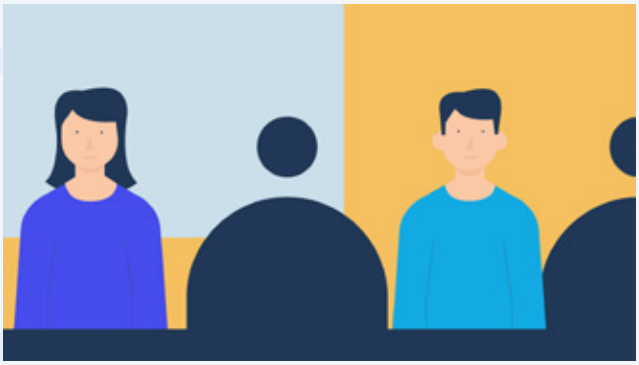
knowledge is transferable. This was partly done based on a theoretical framework on knowledge transferability and partly based on experiences practical examples from local stakeholders. A distinction was made between transferability of the BINGO methodology and transferability of site specific outcomes.

What was achieved?

BINGO delivered aggregated values in terms of benefits, cost simulations and social added values of adaptation strategies and measures per research site. These results were an important input to BINGO's work. The result of the economic and societal analysis was reported in an impact report related to specific measures for each research site. BINGO provided the recommendations and suggestions for implementing the best transition path for each site, dealing with concrete (detailed) results, with the focus on implementation and decision support.
Additionally, a portfolio with adaptation measures was created, which can be consulted online. This tool allows the decision makers to share and select the best measure according to their major issue and helps them to plan the implementation of new/ adapted measures to address expected impacts.

3.5 Ensuring Excellence and Actionable Research



BINGO provided an innovative structure to improve communication among researchers and non-researchers, developing activities which supported a structured common language for the project and produced design guidelines to create and enhance future collaboration between researchers and end users/organisations.
BINGO aimed at ensuring an effective participation of the different end users, water managers and decision makers in its activities. The work developed required input from the local partners at the 6 research sites to ensure that research outcomes were suited to their needs. For this to happen, the targeted stakeholders needed to feel comfortable in sharing their experiences and to feel engaged in coproducing solutions together with the BINGO researchers. This engagement was prepared by inviting stakeholders to participate at face to face meetings, or workshops, which were designed

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as sequential meetings with specific agendas and targets to allow building connections and willingness to collaborate and co-produce relevant inputs all along the project. To be successful in this task, BINGO:

- created and animated a cross-cutting Communities of Practice (CoPs) as a mutual learning setting;
- worked and ensured a common BINGO tool box and skills development to establish productive relationships between researchers and non-researchers; and
- created actionable research labs where complex problems could be addressed and developed to further actionable research solutions.

Because of this experience, BINGO can offer a set of tools designed to facilitate and ensure that researchers and end users/decision makers are able to cooperate in a positive manner, building shared awareness and knowledge, leading to high level research designed to give answers to the society needs.

3.5.1 Animation and facilitation of a Community of Practice

This task intended to animate and sustain a CoP, engaging all partners (Wenger, 2009). The CoP enabled the mutual learning process based on shared awareness and knowledge and inspired more adequate approaches and solutions. BINGO CoP´s experience was guided by a shared "CoP Roadmap" in the six research sites, organised in 6 face-to-face interactions (see Figure 4):

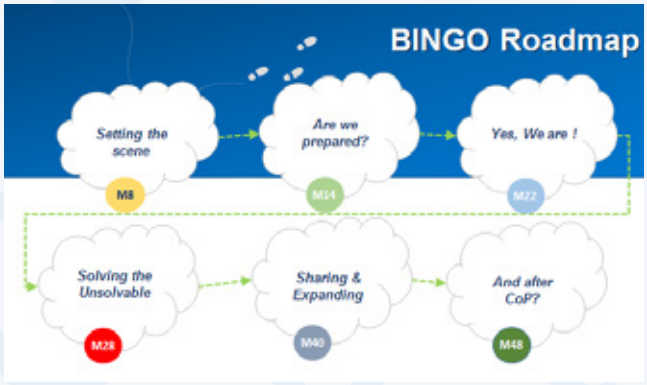

Figure 4: BINGO CoP Roadmap

This CoP also functioned virtually as a web-based discussion e.platform (virtual multi-stakeholder platform established in Basecamp, one for each research site since the national language was chosen), with active participation from the end user partners. This e.platform was launched at national workshops at the 6 research sites and contributed to energise, strengthen and deepen the CoP network, cross-fertilisation learnings, and shared awareness and knowledge. Collaborative and active methodologies were used among researchers and end users, aiming at co-production of a shared repertoire of information, experiences, solutions and practices for a common

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understanding of levels of uncertainty of BINGO outcomes and how this may influence decision-making on mitigation actions. Results of the CoPs are available online here.

3.5.2 Development of researchers skills and tools to construct win-win cooperation with stakeholders

Previous experiences of research initiatives that aimed to create interactions with end users, water managers and policy makers are often evaluated as limited in their potential for actionable exploitation. Participants usually claim of non-equal or just casual engagements and involvement. To change this pattern, BINGO focused on providing to researchers "back-office" information, tools and collaborative skills development opportunities (cross-learning moments) in order to enable them to improve making knowledge alliances. Based on this experience, BINGO produced guidelines designed to create, feed and enhance better "win-win" collaborations between researchers and the players in society that are in need of solutions derived from research.

3.5.3 Actionable Research Lab

BINGO promoted the meeting between researchers and the local partners by creating the possibility and the place where they could engage together and enable actionable research and action. The large panel of actors boosted trans-disciplinary insights about concerns, doubts, interests, difficulties and/or unexpected limitations to explore challenges or solutions. This information fed the research activity by focusing the needs and problems that were solved in BINGO. The Actionable Research Labs worked on complex problems/challenges and explored them, and provided the opportunity to respond to the needs of researchers and non-researchers placed in through open and clear communication between researchers and the society. The methodology is based on social labs principles and worked on the base of Design Thinking framework (Univ. Standford) and of "soft system methodologies" (Checkland & Poulter, 2006). These approaches are a process for problem-solving with the intent of an improved future result. The results from these labs fed the CoP network and are available here.

What did we achieve?

BINGO established a methodology and approach to ensure that the researchers and the local stakeholders will cooperate, building shared awareness and knowledge.

Communities of Practice were the result of: a mutual learning setting where different people meet, ensure a common language and develop communication skills to establish productive

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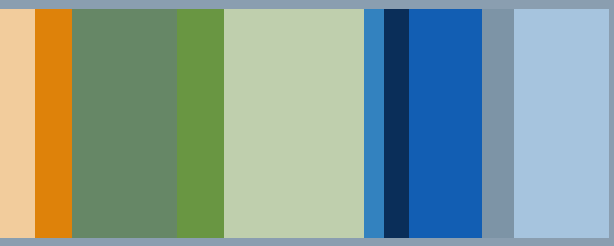
relationships between researchers and non-researchers. Within the CoP roadmap were actionable research labs where complex problems can be addressed and developed to further actionable research solutions.

All of this work has led to a productive, cooperative and fun project, bringing together many people from different places, knowledge and backgrounds to reach the common project goal: a better future under Climate Change.



4 THE RESEARCH SITES

4 The Research Sites

BINGO was built around six research sites in Europe that represent challenges in terms of water management options and approaches. The research sites have been selected to cover a representative range of climate-water conditions and based on a number of criteria, such as expected strong impacts from climate change, previous R&D knowledge, end users in need of solutions, high potential for innovation and replication and competing water demands. There is a large variability of situations that BINGO tackled, both from the climate scenarios and the water cycle changes perspectives. For instance, the research investigated services such as water supply, urban drainage and water irrigation which are of strategic importance to society. BINGO was able to understand how lakes, reservoirs, rivers and groundwater, in Northern and Southern Europe, are likely to be impacted by Climate Change, and subsequently evaluate the risks and produce tailored adaptation measures.

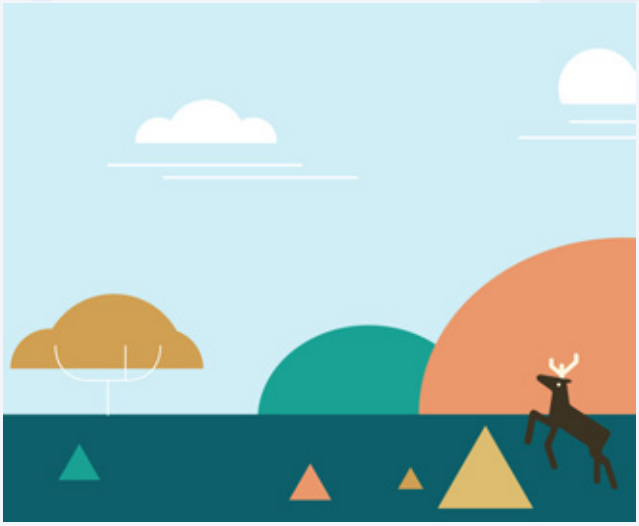
Figure 5: The range of water systems, strategic uses, and key problems addressed at the BINGO research sites.

4 The Research Sites

The boxes summarise the key achievements at the six Research Sites. Sections 4.1 to 4.6 describe the water systems, strategic uses, problems and solutions at each of the six sites in more detail.

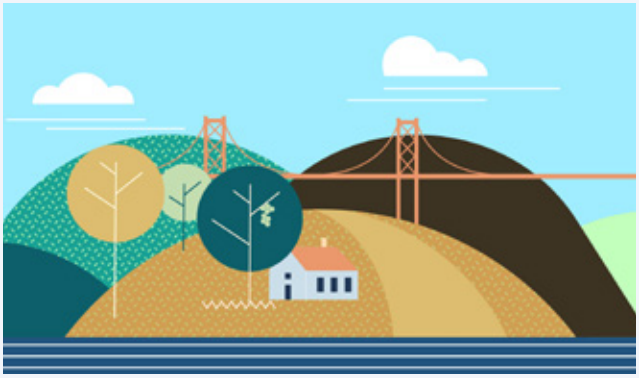
Veluwe

- Making groundwater a more prominent topic in the overall management of the Veluwe and involving local stakeholders in different policy platforms
- More knowledge about effects of Climate Change on the groundwater system of the Veluwe
- Insight into the impact of possible adaptation measures



Tagus

- Hydrological (surface and groundwater) and estuarine modelling to project flows and salt water contents based on decadal CC meteorological predictions
- Knowledge improvement on key risk factors and vulnerabilities of water dependent socio economic activities (public and agriculture water supply).
- Implementation of a comprehensive risk management approach for risk reduction concerning water sources for public water supply and agriculture
- Testing adaptations plans to "next-decade" projections in public water supply
- Identification of requirements to improve water resources governance practices
- Development of a Tagus water resources management model to help in assisting decision making and CC adaptation



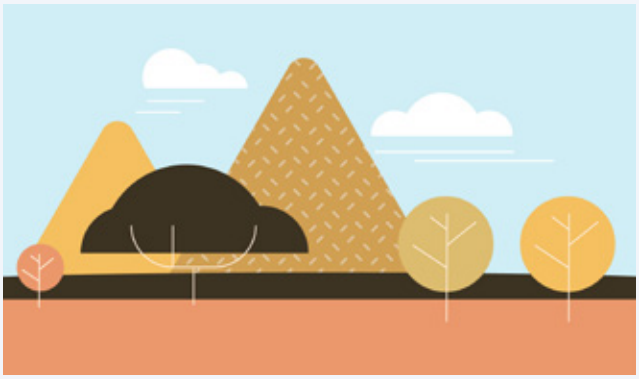
4 The Research Sites

Wupper River Basin

- Relevant experience on how to handle climate data from circulation models
- For the interpretation of modelled discharge from decadal predictions, statistical parameters should be used for comparison instead of absolute quantities to avoid one-to-one correspondence,
- Land use changes for the next decade do not play a significant role on runoff generation. Water use scenarios, on the other hand, proved to be most sensitive for the Größe Dhünn Reservoir - all decadal members reflected the same trend, indicating a slight decrease of water availability for the next decade.
- Soil moisture measurements can be easily implemented (new data transfer techniques) and are very helpful to improve modelling of water fluxes.

Troodos

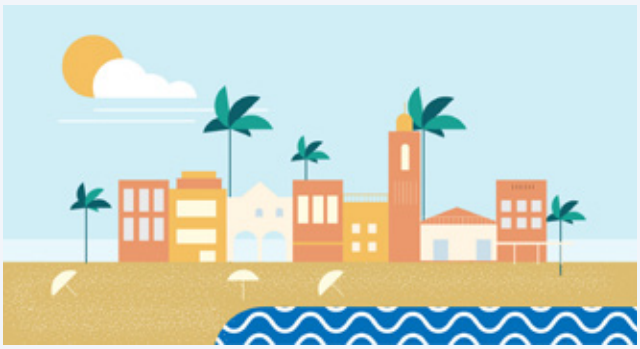
- Successful downscaling at 1x1km resolution of rainfall extreme events
- Successful use of high-resolution downscaled rainfall events in hydrological models
- Model used for Flood Directive Implementation - Observed Rainfall data from the relevant Meteorological Stations
- Model used in BINGO - 1×1 km high-resolution downscaled rainfall.
- One of the members of the ensemble set produced excellent results compared to the results of the model using observed rainfall data
- Calculation of flood flows of extreme future episodes under climate and land-use change conditions
- Understanding of the effectiveness of Tamassos Dam under various initial dam conditions scenarios
- Flood maps in place.



4 The Research Sites

Badalona

- Innovative technological solutions supporting decision-making processes, such as:
  - 1D/2D coupled model for urban flooding impact assessment - Risk maps for pedestrians and vehicles in the event of flooding, which will be included in the current emergency protocols (civil protection)
  - Integrated sewer and marine modelling for CSOs impact assessment - Methodology for CSOs pollution estimation based on rain intensity
- Roadmap for an effective Climate Change adaptation: Consensual list of adaptation measures and Cost Benefit Analysis (CBA) for each of the alternatives, including cost of inaction.
- Engagement and active participation of multiple stakeholders in: Flood and CSO risk management processes and Climate Change adaptation and resilience of urban drainage system



Bergen

- Future climate projections for Bergen, both near- and long term, as well as planning and design tools.
- Impacts on Combined Sewer Overflows (CSOs): Model development and identification of problematic CSOs
- Risk assessment: Frequency analysis and vulnerability analysis
- Adaptation measures and strategies: development of a digital platform for public involvement and decision support table for adaptation measures

4 The Research Sites

4.1 Tagus

The Tagus river basin has an area of 80600 km², 30% of which correspond to the downstream catchment in the Portuguese territory.

The BINGO Research Site Tagus focused on the lower part of the Tagus river basin, aiming to:

- Assess how the potential changes in surface water flow regimes will jeopardize the current and future planned water uses;
- Determine how potential reduction in aquifers recharge and, in coastal lowland areas, possible saltwater intrusion may reduce the availability of groundwater to agricultural uses and water supply;
- Assess Climate Change impacts in the Tagus estuary bordering lands where expected sea level rise, possibly associated with more frequent storm surges, and salt water intrusion are the driving forces;
- Propose a Framework for Managing the Risk (FMR), aiming at helping to sustain key economic sectors and the environment and protect people and property in Tagus Research Site.

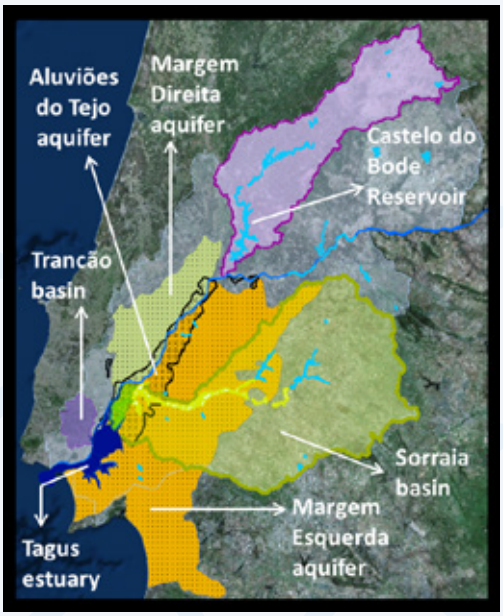


Figure 6: Water systems from the Tagus lower basin studied

Which sectors did it involve?

The Portuguese research site addresses Climate Change adaptation of key sectors, one concerning an important public service water supply, and the other concerning agriculture, one of the most relevant economic activities in the region. The Tagus CoP also engaged several actors from national, regional and local organisations and water users' associations.

Water being the central topic in BINGO, climate change adaptation essentially focusses on how changes in water availability and quality compromise both sectors and how they should

4 The Research Sites

prepare themselves to deal with these changes. Reduction in water availability and quality degradation, associated with more frequent and intense droughts, were the main concerns of both sectors. However, in some specific cases, inundations were also of concern, if due to storm surges in the estuary or other events that either increase the salt water intrusion in the abstraction points or cause farming lands inundations with high salinity content and population unsafety.

What was done?

Risk management (assessment and treatment) for water dependent sectors was carried out both for water scarcity and inundations. First the impacts were assessed and then risks were managed through a Risk Management Process approach.

In order to study the impacts of Climate Change on surface water resources and detect vulnerabilities in the current water uses due to water scarcity induced by new rainfall regimes, two main case-studies were selected: i) The Zêzere River basin (a northern Tagus tributary), where the main water use is in Castelo de Bode Reservoir for power generation, which is not consumptive, and ii) The Sorraia River basin (a northern Tagus tributary), with two main reservoirs in the headwaters, for irrigation purposes in the downstream valley.
For groundwater, the objectives were to study the impacts of climate change (namely droughts) in the recharge of four selected Lower Tagus aquifer systems and, for three of them, to study and analyse the corresponding impact in the groundwater piezometric levels.

Also modelling Tagus estuary for water availability and inundation was carried out. Local stakeholders have been actively engaged in six CoP workshops and an open event was promoted in a local public space with the population to share and discuss BINGO co-productions and issues.

Which were the main results?

Better understanding of the river flows, water availability, inundation and salinity dynamics in the Lower and Tagus estuary was achieved. The main conclusions were:

- the gross majority of the rainfall-replicas' input projected for the decade 2015-2024 generates groundwater recharges and river flows that are not very different from the historical records. Also storminess is not expected to increase in the near future, but the hazard will increase marginally due to sea level rise;

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- extreme storms lead to the overflowing of existing dikes and the inundation of extensive agricultural land;
- low river flows prevent the water uptake for irrigation due to the increase of the salinity upstream and the problem is aggravated for longer drought periods;
- drought can lead to mild groundwater drawdowns in multi-year droughts.

What is BINGO's legacy in Tagus?

Lower Tagus region has always been prone to climatic variability. Climate Change adaptation is in fact not a novelty as the region suffered already several extreme periods but a process that requires optimization of already existing practices.

BINGO provided new and useful information for the stakeholders dealing with agricultural activities and water supply in the Lower Tagus and estuary. A better understanding of the water availability, inundation and salinity dynamics was achieved, which provides the stakeholders with information that will support decision-making during the development of their activities. All the mathematical models applied and/or built within the BINGO project will be used in future related studies.

The flow in the Tagus River is mainly controlled by decisions on the operation of dams. Therefore, from the undertaken studies the importance of external vulnerabilities was highlighted in all case studies of Portuguese research site, identifying integrated water resources management and water resources governance as a key issue for public water supply, agriculture and population uses. In fact, for this Research Site, adaptation is centered on improved integrated water resources management.

4.2 Badalona

Figure 7: Plan view of Badalona.

4 The Research Sites

Badalona is a Catalan city with 215000 inhabitants and an extension of 21 km² between the coastal mountain range 'Serralada de la Marina' and the Mediterranean Sea. The city experiences flash floods during intense rainfalls due to the steep slopes towards the flat urban area, the high degree of imperviousness and the limited drainage capacity. Also, Combined Sewer Overflows (CSO) occurring during rainfall events larger than few millimetres contaminates the sea water.

Which sectors did it involve?

The company Aquatec was the responsible of the Badalona research site. The main partners that were actively involved into the project through continuous interaction and meetings were the municipality of Badalona, the Barcelona Metropolitan Area (AMB) entity, the mixed company for the management of the supra-municipal sewer system and sanitation of the Barcelona Metropolitan Area and the Water Technology Center Cetaqua.

Further local and supra-municipal stakeholders like Technical University of Catalonia, Catalan Water Agency (Agència Catalana de l'Aigua) and Diputació de Barcelona participated during the four project workshops that took place in Badalona and the established Community of Practices (CoPs).

What was done?

The work that was done at the research site included:

- The definition of the specific activities within the project and the related coordination and management plan.
- The prediction of future climate based on decadal climate predictions and long term climate projections. Future rainfall was then statistically downscaled.
- New equipment was installed, several field campaigns were executed and existing water quality and quantity data were gathered.
- A large set of models (a 1D/2D urban drainage coupled model, a sediment transport module, an integrated urban drainage and sea water quality model) was developed, calibrated and validated.
- Full risk assessment together with tangible and intangible impacts was developed according to a detailed Risk Management Process established with local risk owners. Flood risk maps for pedestrians, vehicles and buildings were computed. Also risk for bathing people was assessed.
- Structural and non-structural adaptation measures like new pipes, detention tanks, green adaptation measures and early warning systems were evaluated and prioritized based on both their capacities of reducing risks and impacts and a cost-benefit analysis.

4 The Research Sites

Which were the main results?

Urban flood hazard and risk maps for pedestrians, vehicles and infrastructure were computed for both present and future rainfall. Actual flood damages would increase by 30% due to Climate Change. Also, the risk for people bathing was assessed. Finally, a prioritization of different adaptation measures was done. For example, a city-scale implementation of the proposed structural measures has higher costs than benefits. On the other hand, it can significantly reduce flood and CSO risks.

What is BINGO's legacy in Badalona?

The following practical outcomes will remain at the research site:

- Innovative technological solutions to support decision-making processes: a 1D/2D coupled model for urban flooding impact assessment and an integrated sewer and marine model for CSOs impact assessment
- Risk assessment procedure for urban flooding including specifc hazard criteria, vulnerability indicators and risk matrices
- Flood risk maps for pedestrians, vehicles and buildings to be used by civil protection and other municipal departments
- Conceptual models for Floods and CSO Early Warning Systems
- Direct and indirect flood damage assessment
- Methodology for CSOs pollution estimation based on rain volume
- Risk treatment and cost-benefit analysis of adaptation measures including the cost of inaction
- Report on how collaborative processes (CoP) are crucial in decision-making processes concerning Climate Change: risk definition and perception and CC adaptation roadmap.

4.3 Troodos

The BINGO Cyprus team investigates climate-water issues in two watersheds along the semi-arid, northern slopes of the Troodos Mountains. In Peristerona Watershed the main problem is drought in the rural plains. Streamflow from the upstream areas recharges the groundwater resources

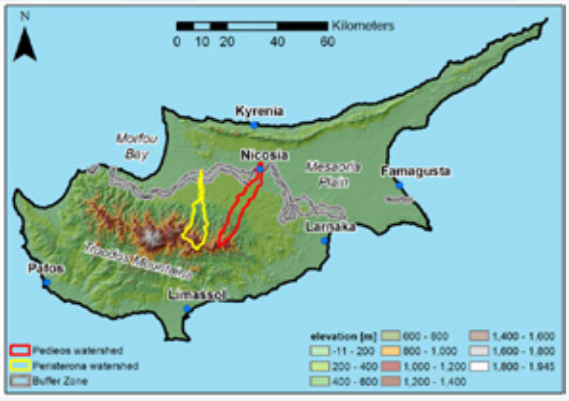

Figure 8: Map of Cyprus with the Troodos Mountains, Peristerona Watershed (yellow) and Pedieos Watershed (red).

4 The Research Sites

downstream. In Pedieos Watershed the main problem is flooding in the downstream urban areas.

Which sectors did it involve?

The BINGO research in Peristerona Watershed addresses the two main water uses: domestic water supply and agriculture. Community councils are responsible for domestic water supply, and water user associations and farmers manage irrigation water. Government authorities are responsible for water resources, policy and technical support. Sector organizations provide technical advice. In Pedieos Watershed flood hazards are an important concern for the water authority (WDD), which is responsible for the EU Flood Directive.

What was done?

The overall objective of BINGO research was to observe and model current and future water resources and identify and assess adaptation options with stakeholders. Specific actions included:

- Realistic simulation of past rainfall extremes with the Weather Research Forecasting (WRF) model
- Simulation of possible future rainfall extremes (2015-2024) from the global MiKLIP decadal prediction system
- Modelling the extend of flooded areas in Pedieos Watershed for possible future extremes and different land use scenarios
- WRF-Hydro model parameterization with high resolution observational datasets for northern Troodos
- Establishment of a climate-water Community of Practice (CoP) for downstream Peristerona Watershed
- Monitoring of forest water balance components and streamflow during hydrologically contrasting years
- Risk analysis for domestic water supply and irrigation in downstream Peristerona Watershed
- Multi-criteria assessment, cost-effectiveness, equity and governance analysis of four adaptation options.

Which were the main results?

- Modelling results indicated that the number of drought years where public water supply will be constrained will increase to 15 drought years (53%) for the period 2020/21-2049/50 compared to 6 drought years (21%) for 1980/81-2009/10 (RCP 8.5 scenario). For irrigated agriculture, the number of drought years will increase from 20% to 53%, respectively. The maintenance of recharge check dams was found to be the most cost-effective solution for mitigating the effects of Climate Change on water resources.

4 The Research Sites

What is BINGO's legacy in Troodos?

- A high-resolution, dynamic climate downscaling methodology for Cyprus
- WRF-Hydro set-up for coupled climate-water modelling in Cyprus
- Improved capacity to conduct flood mapping studies for Climate Change and land use change scenarios
- Quantification of forest water balance components for northern Troodos hillslopes under different rainfall conditions
- Climate-water Community of Practice, connecting community leaders, farmers, government officers, consultants and researchers
- Improved understanding of climate-water risks for community councils (domestic water supply) and irrigation associations (agriculture) through a risk analysis approach
- Methodology for identification and integrated assessment of climate adaptation measures, in close cooperation with stakeholders, to improve adoption.
- Cost effectiveness of four adaptation options: groundwater recharge check dams, desalinated water supply, irrigation scheduling, treated sewage water use for irrigation
- Motivation to develop an integrated probabilistic hydro-economic analysis to further improve the sustainable implementation of adaptation measures.

4.4 Veluwe

The Veluwe research site is situated in the centre of the Netherlands. The force of glaciers in the ice ages formed the characteristics of the landscape with ice pushed hills. The groundwater levels are deep in the centre and shallow at the fringes. The land use consists of forest mainly. Residential areas and dairy farming surround the Veluwe. Its subsoil contains a large reservoir of fresh groundwater that is exploited for the production of drinking water.

Which sectors did it involve?

Provincie Gelderland and the public water supply company Vitens are partners in Bingo. The Water Board Vallei and Veluwe is closely involved in the entire BINGO project.
Other organisations who have participated in the Community of Practice are Nature management organisations, Organisation of private land owners, Brook foundation, Van Hall Larenstein University of Applied Sciences and the municipality of Amersfoort on behalf of the municipalities in the Gelderse Valley.

What was done?

Within the BINGO-project the groundwater model AZURE was improved. For the Veluwe three Climate Change ensembles have been calculated, dry, moderate and wet. Because the Veluwe

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responds slowly to changes in climate, also an ensemble with three consecutive dry years has been calculated. For three possible measures (sprinkler restrictions, land use change and infiltration of surface water) the change in the groundwater level was calculated, both for the current situation and for the climate ensembles. Also experiments have been carried out for improving knowledge and measurement methods of the evaporation and interception of trees.

Five workshops were organised to reflect together with the stakeholders on the consequences of Climate Change for function and the possible adaptation measures and their effects.
A final symposium was organised dedicated to disseminating the final results. The event was attended by more than 80 people, including policy makers from different levels of government, scientists, NGOs (Non-Governmental Organisations) and local entrepreneurs.

Which were the main results?

BINGO has provided new information on the effects of Climate Change on the groundwater system in the Veluwe. In the short term, the changes fall within the natural variation. However, several dry years in a row can cause drought damage.

If measures are needed, land use change has much more effect on groundwater recharge than groundwater abstraction. The Veluwe is a huge groundwater system. If we want to influence this system we have to take large-scale measures.

The involvement of stakeholders in a Community of Practice makes groundwater a more prominent topic in the overall management of the Veluwe.

What is BINGO's legacy in Veluwe?

The experiments that have been carried out provide a better estimate of forest and grass/heather vegetation evapotranspiration. This knowledge is transferable to other sites with the same types of vegetation. Through a better understanding of the groundwater system and of the evapotranspiration, the groundwater model Azure is improved. Future projects will benefit from this improved groundwater model.

More knowledge about the impact of adaptation measures are important results for other projects regarding groundwater management. If it is necessary to increase the groundwater level at the Veluwe, large-scale measures are needed. Small-scale measures have little effect.

4.5 Wupper

The Wupper catchment area lies in the state of North-Rhine Westphalia, Germany, with an area of 813 km² and a river network of approx. 2.300

4 The Research Sites

km. The Große Dhünn reservoir is located within the Dhünn catchment area, the main tributary of the Wupper. The Wupper then meets the Rhine at the city of Leverkusen. The Mirke Creek in Wupper River Basin is a typical brook in that area for flush floods.

Figure 8

The topography varies between 40 and 500 MASL, with mean annual precipitation (mean annual precipitation) ranging from 750 to 1.450.

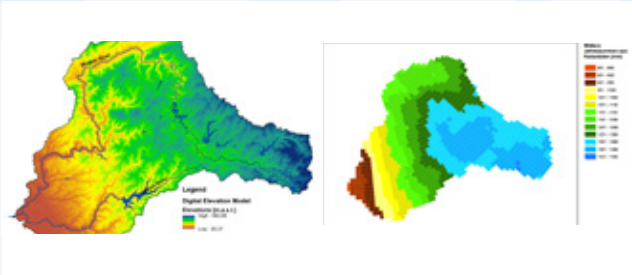

Figure 9

Which sectors did it involve?

Most relevant stakeholders include federal authorities, district governments, municipalities, environmental agencies, drinking water suppliers, power generating plants, trade and industrial organizations, and insurance organisations. Stakeholders were engaged to contribute perceptions and understanding about Climate Change. Case studies as well as adaptation measures and structural gaps were defined together with the stakeholders. The case studies were: (i) too much water (flash floods at Mirke Creek) and (ii) not enough water (water availability stress at Große Dhünn reservoir).

What was done?

A set of (hydrological) impact models were set-up, calibrated, and validated to investigate the local effects of Climate Change in combination with land and water use scenarios. The models were driven with meteorological input data based on decadal predictions, and climate projections.

Past extreme dry periods were evaluated based on long-term precipitation time series, indicated by indices like Standardised Precipitation Index (SPI) and the the Standardised Precipitation - Evapotranspiration Index (SPEI) and correlated to storage volume of the reservoir. The simulated future scenarios were sorted in the same way to determine possible developments. For flash floods extremal episodes with heavy rainfall events were simulated based on high-resolution downscaling. A network of soil moisture sensors and tensiometers

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were installed in the catchment upstream of Große Dhünn reservoir accompanied by field tests and laboratory analysis. The monitoring of soil moisture and tension contributed to a better knowledge of the flow processes and the improvement of the hydrological models based on measurements.

Which were the main results?

Temperature and evapotranspiration rates are expected to increase, mainly in summer, with a meaningful impact on rainfall regimes. The inflow to Große Dhünn reservoir is likely to increase in fall and decrease in spring. In the Große Dhünn reservoir catchment land use changes are minor due to protection zones, but reservoir volume proved to be highly sensitive to the different water use scenarios. Less small events and more extraordinary events are expected related to flash floods, which have a high impact on damage costs.

What is BINGO's legacy in Wupper?

BINGO led to a better understanding and knowledge about the use and interpretation of climate data based on regional models in close interaction with the meteorologists. This has led to better communication between stakeholders and possible future development and support for the decision making processes in adaptation. Additionally, it provided the knowledge on how fundamental it is to capture accurately extreme convective heavy rainfall, high temporal and spatial resolution. The technical results from the BINGO project also improved models and knowledge on soil processes, including technical infrastructure and processes on how to manage and analyse large amount of data sets.
In addition, the determination of representative indices demonstrated to be a robust method for comparison between several data sets and uncertainties.
A concept of prioritisation of effective adaptation measures was developed, including also non-monetary weighting. For flood risk reduction not only structural measures were analysed and proposed, but also property protection is identified as potentially meaningful.

4.6 Bergen

Bergen is the second largest city in Norway, located on the west coast of the country. Its pronounced topography and exposed location make it one of Europe's rainiest cities. The city has a robust water supply comprised of several coupled surface water reservoirs, but the water and sewage networks are old. This entails leakages in the water distribution network and pollution from combined sewer overflows to receiving fjords. In the BINGO project, these challenges have been addressed in the context of Climate Change.

4 The Research Sites

Figure 10: Map of the Bergen research site showing main drinking water reservoirs (Jordalsvannet, Svartediket, Sædalen, Espeland) and area with combined sewer system (Damsgård).

Which sectors did it involve?

The municipality in Bergen is the end-user of the BINGO project and was involved as a project partner. Different agencies of the municipality were involved in the Community of Practice (CoP) stakeholder group. These included the Agency for Water and sewerage works, Planning and building services, Housing and redevelopment, the Department of urban development, and the Department of climate, culture and business development. Other stakeholders involved were research communities and residents.

What was done?

The work at the Bergen research site have been two-fold, focusing on 1) Future drinking water availability, and 2) Reducing overflows from combined sewer systems.
For the first objective, a model chain comprising statistical downscaling of Global climate model simulations, hydrological modelling of inflow to drinking water reservoirs and a reservoir storage balance has been set up. The model chain was run with long-term scenarios for future climate, population growth and water demand.
For the second objective, the Stormwater Management Model (SWMM) has been set up for the combined sewer system in the Damsgård area of Bergen – an area currently transforming from a heavily industrialized site to urban housing and recreational spaces. The SWMM model was run with 10x10 years of decadal climate prediction prepared in the BINGO project, which allowed for a detailed risk identification, assessment and proposals for treatment options based on risk level and cost-effectiveness of adaptation measures.

Which were the main results?

The main results of the BINGO project for Bergen are:

- dynamically and statistically downscaled climate projections for the short term (decadal) and long term (centenary), respectively,
- Calibrated hydrological and hydraulic models;
- Detailed risk identification and assessments,
- Suggestions for adaptation strategies and measures, and
- A Community of Practice for further interdisciplinary collaboration.

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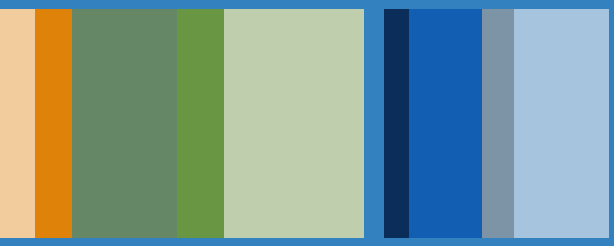
What is BINGO's legacy in Bergen?

In Bergen, much effort has been put into understanding climate data and how they can be of practical value to end-users in planning and design. This work has been an exercise of transferring climate research to practical knowledge, which has resulted in a better comprehension of the type and format of climate data needed for different hydrological processes and for different tasks such as investigations, system planning or component design.
The CoP framework has facilitated interdisciplinary teamwork and helped increase the level of collaboration across municipal agencies and departments. The CoP stakeholders now have a common understanding of challenges. This will help them to succeed in holistic planning. This co-creation process has also highlighted the value of public involvement and the municipality has started several initiatives to better communicate with their citizens. By the end of BINGO, the municipality continues collaboration with schools and students and keeps developing their digital platform for public involvement.



5 How Bingo Reached Society

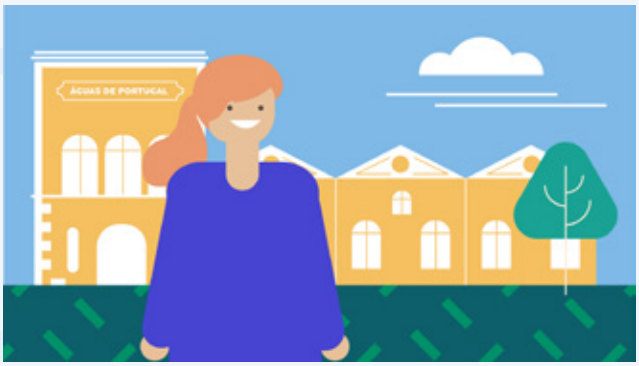
5 How BINGO reached society

BINGO involved many types of stakeholders in its process. We reached out to all 6 research sites to find out more about their experiences with the BINGO project. Here are their stories:

Representative of a farmer's association, ABL - Tagus Research site

"What I feel in terms of 20-30 years is that the agriculture in my area has been suffering great changes, it became much more technological, the farmer has been investing and evolving in the knowledge and methodology of agricultural production. What I feel throughout BINGO, and linking to all the shared opinions and the themes that were debated, is that it makes us think about Climate Change in a way that is more concrete and detailed, as it has an application scope which is much better defined."

Representative from EPAL, a water supply company - Tagus Research site



"Being a member of the BINGO family is, to me, both an honour and a challenge. It is an honour because I became part of this great team, which I know that has been carefully chosen in order to be able to fulfil the goals set out for the project. And it is a challenge because those goals are leading edge in such an important and complex subject as Climate Change Adaptation. Notably, climate predictions, Communities of Practice and liaising the different parts of the project through a risk management approach are just some examples of this."

5 How BINGO reached society

Ecohydrology & Groundwater Advisor at Waterschap Vallei - Veluwe Research Site

"The BINGO project provided us with new knowledge concerning the "hidden part" of the hydrological cycle. In our watershed of the Vallei and Veluwe Waterboard, the infiltration of rainwater in the sandy ice-pushed ridges of the Veluwe is crucial to many derived functions along its outlines. BINGO cleared part of the puzzle as to which portion of rainfall is actually infiltrated into the subsoil. Next, we need to understand how this infiltration will be expressed in the water tables around the Veluwe. In that way we can better predict the effects of Climate Change on the nature functions (streams with high ecological values, seepage dependent vegetation), agriculture (desiccation) and cities (heat islands, groundwater stress)."

Foundation for Nature and Environment in the NW Veluwe - Veluwe Research Site

"On behalf of an NGO in the study area, I have been involved as a stakeholder in contributing to provincial environmental policy since 2014. That was probably why I was asked to participate in the COP. The stakeholder group has never had a formal status but nevertheless we were able to attract participants all the time by providing information, asking for opinions, and organising discussions. The final [BINGO] symposium was fascinating. There was a lot of exchange of knowledge and opinions. The most ambitious element in the recommendations of the project group (authorities and researchers) was: a pipeline between the Rhine and the Veluwemeer for infiltration in three locations. The question remains open to what extent water from the Rhine and from the lake, with chemical compositions different from local ground water, will increasingly mix with local ground water. In this context the Natura

5 How BINGO reached society

2.000 status of a large part of the study area (Veluwe) and of the lake (Veluwemeer) will be important. The same goes for adjacent areas and brooks depending on seepage water from the Veluwe. So there are various hesitations with regard to this idea. An opinion poll in the meeting room showed a majority against infiltration. So we are interested to see what the final conclusions will look like."

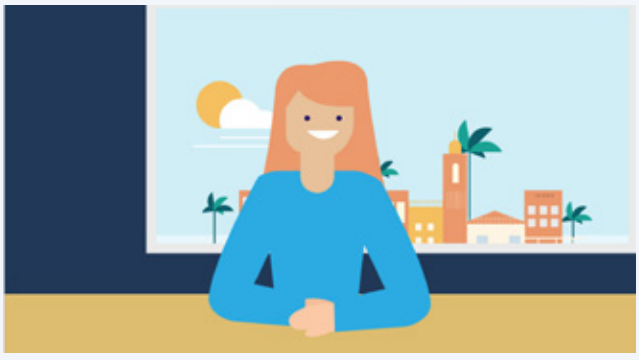
Representative from the Civil Protection and Emergency Planning from the City of Bergen – Bergen Research Site

"I am responsible for the main risk analysis for the City of Bergen. Participation in BINGO has been a useful contribution to my work on risk assessment. Incidents connected to extreme weather, floods, Climate Change and climate-adaptation are among the most serious challenges for Bergen. We need more knowledge and better tools to prevent and to handle these incidents. Participation in BINGO and the interdisciplinary workshops and conferences is an important part of developing better understanding and knowledge on these issues."

Løvstakken Volunteer Center - Bergen Research Site

"We at Løvstakken Volunteer Center are active users of the outdoor recreation areas on Løvstakksiden in Bergen, and we were invited to participate in the BINGO project via the municipality's area initiative. Through participation in the project we have increased awareness of the topic of water and Climate Change. We now also know who to contact when there are problems with stormwater and flood. And not least, we have come to understand that planned measures must be considered in a context and necessary clarifications must be taken to reduce the risk of undesirable consequences related to the measure."

Aigues de Barcelona, Water Integral Cycle Management – Badalona Research Site



5 How BINGO reached society

"BINGO enabled us to understand, broadly speaking, how flood risks are assessed, using Badalona as a case study. We have learned about the complexity involved in weather and climate forecasting, and the uncertainty associated with this. The project plays a key role particularly in the combined sewer overflow to the sea. It is hard for us to quantify and identify the discharge of wastewater to the sea, but through their study of two specific basins in the BINGO project we have used as a pilot project, enabled us to define them. It will be very useful to understand how to act in the future and which measures we need to take."

Decision-maker Badalona city council – Badalona Research Site

"We learned how the impact of Climate Change intervenes in Badalona's rainfall, which enabled us to develop an in-depth study on the vulnerability of Badalona in terms of increased rainfall and find out which areas of the city are most prone to flooding. This provides us the tools to find solutions. An important contribution is to involve different agents who do not work directly with the environment, such as city and urban planning, road maintenance, etc. in the problem of Climate Change and the risk it poses to the city, how vulnerable they are and make them more aware so that they too can incorporate this criteria into their work."

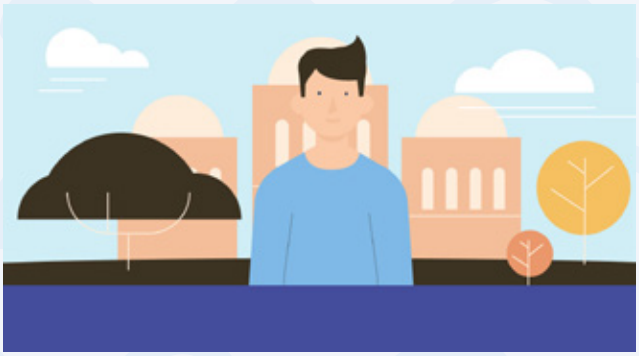
IACO Ltd· environmental· water sustainability – Troodos Research Site

"Having worked for the Cyprus Pedieos case study, one of the most intriguing outcomes of BINGO was the successful modelling of observed runoff events through effective downscaling of observed extreme rainfall events. This enabled us to test different realistic rainfall – runoff extreme event scenarios under different land use and climatic conditions, using a validated/ calibrated rainfall/runoff model, producing thus different flood hazard maps. These outcomes can

5 How BINGO reached society

definitely provide valuable additional information in any flood risk management plan as they can provide additional knowledge on how flood risks can be better defined and alleviated, taking into account additional parameters such as Climate Change, and effective land use management."

Community Leader of Astromeritis Village - Troodos Research Site



"My participation in the European research project BINGO, both as a representative of the local authority but also as an active citizen, and the knowledge exchange with researchers, policy makers, farmers and other stakeholders enriched my understanding of the impact of Climate Change on water resources management. During the [BINGO] stakeholder workshops each participant suggested ways to deal with the problem based on his/her experience and field of action.
Inevitably, the local government and, consequently, the local community, should immediately take precautionary measures on the rational management of water resources and construct infrastructures for the use of recycled water at least for the agriculture and livestock sectors."

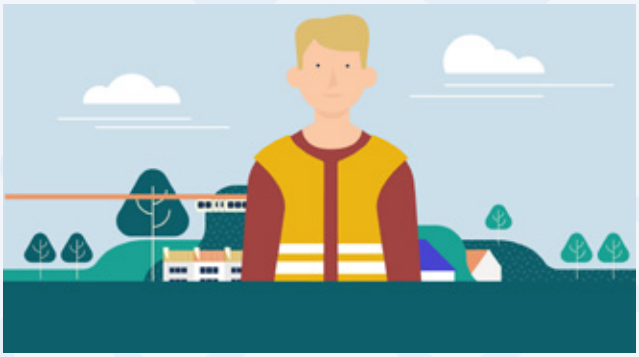
Reservoir operation-department - Wupper River Basin Research Site

"Reflecting the last two years in the context of water management, it is to determine that especially in one of the model regions investigated within the project BINGO, namely Wupper River Basin / Germany, two opposite extremes has to be observed: an extraordinary pluvial (flush) flood event with high economic damage and unusual low reservoir level.
This underlines that future management strategies must be aligned to significantly changed hydrological amplitudes.
The approach within the BINGO project to pursue precisely this topic and to present a more robust sketch of the possible effects of Climate Changes on - and thereby the weaknesses of - the currently still applied conservative water

5 How BINGO reached society

management framework, is an important step towards a sustainable design of infrastructural developments within the context of reliable water supply for the next generations."

Wupper River Basin Research Site



"First of all, it became apparent which conflict potential, risks and challenges due to increasing weather extremes already existing and also can be expected in the future.
It became clear that essentially two weather extremes should be considered:

- *Too much water: flooding caused by torrential rain*
- *Too little water: ensure reliability of water supply*

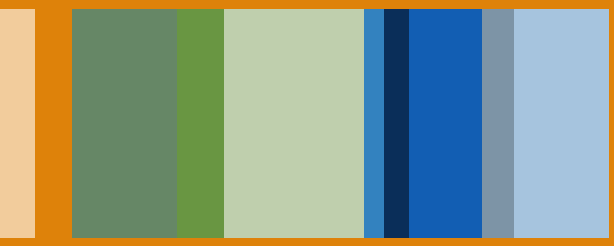
As part of the examination and investigation of the two extremes, it became clear that a comprehensive database is immensely important in order to be able to develop plans and measures. Particularly it turned out that many actors are affected by these extremes and that corresponding reactions are planned and expected.

Options for action required by Climate Change should be embedded in all decision-making bodies such as urban planning and development, nature conservation planning, reservoir management and local development planning, as well as in water associations, supervisory authorities, municipalities / cities / districts, agriculture and nature conservation. In particular, every citizen is also responsible and therefore has to understand the effects of Climate Change and from that to derive his individual actions accordingly.

Special attention is to be given to extreme dry periods and the associated water shortage. A supra-regional approach is mandatory to secure an effective water quantity management for the future and thereby to ensure the provision of drinking water for the citizens.

BINGO is an experience that brings extensive and sustainable findings and derived substantial future planning.

It remains challenging!"



6 GUIDELINES FOR METHODOLOGIES

6 Guidelines for methodologies

BINGO generated different types of exploitable results, which are both tangible and intangible outputs, such as data, knowledge and information. Overall, the BINGO project has produced two types of results:

- The ones which are site-specific, due to the local singularities, but can be possibly transferrable to sites with similar characteristics (example: hydrological models, maps, etc).
- The ones which can be used outside of the scope of the BINGO Project, transferrable to other sites, projects or companies (example: methodologies, tools, guidelines, etc...). These results are the methodologies which were applied in the BINGO project and tested approaches that can be used as they were in BINGO or as inspiration.

The first type results are the research site results, which are exploitable by the several entities and are relatively project-specific, as they produced solutions to project-related issues in the sites where BINGO was implemented. These are covered by Section THE CASE STUDIES of this e-book.

The second type results, which are described in the guidelines presented in this section, refer to the BINGO outputs which are transferrable to other contexts, and include methodologies, strategies, models and approaches which were applied in the BINGO project and produced the first type of results.

The exploitable results produced by BINGO address the specific needs of the different stakeholders involved in water management in through an innovative approach and have a competitive advantage over the knowledge that currently exists. They are of great relevance to cities, regions and specific activities using water such as abstraction of water for human consumption and irrigation all across Europe and beyond, and have a significant exploitation potential.

6.1 Collaborative Management in Climate Change Adaptation

Click this button for the complete guidelines

Water managers and other type of decision makers often need scientific information to match their decisions (typically short term and local) to complex, long-term, large-scale challenges such as adaptation to Climate Change.

The main goal of these guidelines is to share and expand the collaborative management experience of the BINGO's Coordination and Management process during the 4 years development of the project. Alliances between researchers, managers and stakeholders in challenging and effective experiences of knowledge co-production were promoted. In a joint work we have addressed the scientific

6 Guidelines for methodologies

production (i.e. climate predictions, hydro-models and risk management) by recognizing the relevance of going beyond the scientific areas and building dialogues and cross-learning. We are clearly convinced with our experience in BINGO that co-production is especially appropriate for complex problems (i.e. Climate Change and impacts on water) involving multiple special and temporal scales, problems where neither scientists nor managers can specify needed science products in advance or situations in which managers need ongoing guidance on proper use of science in a variety of decision-making contexts.

- Engage actively everyone in a common goal
- Ensuring commitment & full acceptance of managerial principles and structure
- Promote good communication and attainment of a common framework
- Face difficulties when they show , enhancing collaborative problem solving
- Use of combined multi-level approaches to get information
- Develop capacity to adapt and move forward
- Identify key success factors and celebrate team achievements
- Prepare for long-term processes and deal with uncertainty
- Develop a virtuous ongoing cycle of preparation, response and revision

6 Guidelines for methodologies

6.2 Dynamical downscaling to 1 km scale – method, rainstorms

Click this button for the complete guidelines

High-resolution climate data are of great benefit to hydrologists and managers of hydraulic infrastructure, but are computationally very expensive to generate. BINGO has developed a transferable methodology for greatly reducing the computational expense of producing such data, focused on the study of extreme precipitation events. This methodology has been translated into specific guidelines to facilitate its implementation:

- Data assembly
- Identification of extremal weather patterns for the catchment
- Identification of local-scale meteorological predictors
- Implementation of classification algorithm
- Dynamical downscaling to convection-permitting resolution

6.3 Application of hydro models

Click this button for the complete guidelines

Hydro models are generally used to represent and predict water fluxes in the past, present and future, from near-real time to long term modelling, e.g. until 2100. The choice of the model is based on the type of water flux to be investigated/predicted. After setting up the model it needs to be calibrated and validated with observed data in order to assess its suitability to represent all relevant natural, anthropogenic and technical processes that drive the water fluxes. Once the model performance is considered to well represent past and present conditions, it can be applied for predicting future water fluxes. Usually, depending on the temporal horizon of the prediction, different climate scenarios/predictions can be used to drive the model, e.g. from hourly/daily forecasts to decadal predictions to RCPs (Representative Emission Pathways) until the end of the century.

Here are the guidelines defined for this methodology:

6 Guidelines for methodologies

- Analysis of the water-system and/ or water problems
- Selection of applicable model
- Model set-up
- Model calibration and validation
- Selection of climate scenarios
- Modelling the impact of climate change
- Selection of socio-economic scenarios
- Modelling the impact of socio-economic change
- Combined modelling of climate and socio-economic impacts
- Assessment of risks and measures

6 Guidelines for methodologies

6.4 Performing risk assessment

Click this button for the complete guidelines

The evolution of Climate Changes still presents a large amount of uncertainty. Water is the central resource in BINGO and how its excess or deficit affects key socio-economic services is the key issue addressed in the project. Adaptation strategies require decision under uncertainty, what is a difficult task by people in charge, no matter its ranking position (policy makers, regulation entities, service provider entities, citizens).
The adoption of an adaptation strategy requires knowledge about a large diversity of information regarding natural or environmental phenomena; conditioning factors influencing the adaptation objectives (political, social, economic, technological, organizational) and affecting the socio-economic key activities; relevant actors; and perception of risk, among other factors.

A risk management approach is a suitable methodology to link all this information and structure it in a way able of providing support to decision making.

BINGO has provided guidelines to develop the most relevant steps of a risk assessment process, based on ISO: 31.000, referring to BINGO experience and their limitations and successes. It aims at being useful to any type of entity performing a first attempt of a risk management process.

- Comunicate and consult
- Establish the context for the risk management process (RPM)
- Risk identifcation
- Risk analysis
- Risk Evaluation

6 Guidelines for methodologies

6.5 Prioritisation between adaptation measures

Click this button for the complete guidelines

BINGO has produced a practical guideline to collecting and analysing measures for adaptation to Climate Change. One of the goals of the BINGO project was to select and analyse adaptation measures as part of an adaptation strategy. We have, thus, applied a stepwise approach to prioritize between these and other measures, using different approaches to elicit stakeholder knowledge and expert analysis. This allowed the different research sites in BINGO to select suitable adaptation measures, supported by stakeholders and grounded in research and effective on a broad range of socio-economic criteria.

In this guideline, the stepwise approach is laid out that was followed in the BINGO project to select and analyse adaptation measures:

- Create portfolio of potential adaptation measures
- Select relevant measures based on risk analysis and stakeholder preferences
- Multi-Criteria -Analysis (1): Develop a set of socio economic indicators to score the selected measures
- Multi-Criteria-Analysis (2): Score selected measures on socio economic criteria
- Analyse adaptation measures on social justice
- Analyse adaptation measures for governance needs using the three-layer-framework

6 Guidelines for methodologies

6.6 Guidelines designed to create, feed and enhance "win-win" collaborations between researchers and stakeholders

Click this button for the complete guidelines

In the BINGO project, the centre point for the coproduction of knowledge at each site has been the Community of Practice (CoP). BINGO proposes a set of guidelines, based on the project's experience on how to facilitate a CoP in a research-stakeholder based setting in order to create, feed and enhance win-win situations. Communication is at the centre of the CoPs, making it an integral part of the guidelines, which are not intended as solution but as a suggested path based on experiences and reflections in the BINGO project. Since BINGO project covers 6 research sites across Europe, it introduces local and cultural adaptations as an important factor. Here are the guidelines defined for this methodology:

6 Guidelines for methodologies

- Design a double-slided communication strategy;
- Designate a CoP facilitator and Design a roadmap
- Built a solid and diverse base for CoP development
- Design a storytelling for each interaction animation and facilitation
- Make everyone aware and comfortable with the etchics code
- Create a collaborative environment and make room for informal interactions
- Create a vision and set expectations and common outcomes
- Engage everyone in co-productions and make room for side-concerns debate and/or detailed side-debates
- Evaluate and celebrate each step's achievements
- Take care of co-productions register, feed-back, and technical reports
- Follow-up CoP other iniciatives and developments (inputs x learning x actions)
- Prepare community for the long haul

BINGO
a better future under
CLIMATE CHANGE

7 Q&A

7 Q&A

7.1 About the BINGO project experience

What is more surprising in 4 years of H2020 BINGO?

The remarkable number of key innovative scientific & practical achievements was not so unexpected due to the high quality of the team. What was surprising more was the inspiring, valuable and transformative process of engaging stakeholders in the Communities of Practice (CoP) and the joint co-production of knowledge. For all the team members it was an incredible rich experience. The power of true collaboration, trust and commitment made the difference in BINGO.

How did BINGO bring science to society?

BINGO brought its key outcomes to different sectors in society and using several ways of communication, fit to the different audiences. They are: oral and written technical and scientific communications; workshops with stakeholders (e.g.: water and water related sector, civil protection, decision makers); videos with testimonials and animations explaining key guidelines; games and scripts for role playing (farmer and politicians dealing with Climate Change) and a musical performance, to be used in schools, in senior universities, in associations, in families, etc. There materials can be easily find and accessible at the BINGO website!

What has BINGO to do with the 4th European Climate Change Adaptation Conference – ECCA 2019?

BINGO was one of the 3 H2020 projects co-organising ECCA 2019, together with PLACARD and RESCCUE. The event took place in Lisbon, Portugal, 28-31 May 2019, gathering 1200 participants - it was the most participated ECCA so far. Moreover, the final conference of BINGO was embedded in ECCA 2019: the project main results and outcomes were communicated through 27 presentations, among oral presentations, sessions and posters, covering all the six themes of the conference.

How would you assess the structure of the BINGO project?

At first stages of the project it was not expected that such a great connection among the different case studies would develop. Although events such as annual meetings and monthly workpackage leaders meetings were scheduled, the team imagined a scenario in which every local team would developed their project mainly on its own, just sharing some results and conclusions with the others in these events.
Not only partners not directly involved to any specific case study such as FUB, SPI and InterSus have been crucial making this link strong, but also the structure of Work packages with its leaders

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from different teams.
Moreover, the annual meetings have allowed every single member of the BINGO team getting to know the reality of the other case studies, getting everybody involved and generating many profitable discussions for the benefit of the whole project, regardeless of the case study.

To sum up, this duality of case studies and workpages structures was a complete success, an effective way to turn the local teams into the global BINGO team.

What are "Communities of Practice" and what role did they play in the BINGO-project?

A Community of Practice (CoP) is a group of significant and diverse stakeholders who share a concern or a passion for something they do, and learn how to do it better as they interact regularly. A CoP is not necessarily consensus-based, but rather fed by diversity, enabling exchanges, mutual awareness, joined perceptions, implication and actions. Member's interactions over time produce resources that affect their practice, whether they engage in actual practice together or separately. They enable collaborative co-production of knowledge, the development of holistic and actionable strategies to address challenges at hand and help the innovative potential of research results to cross the barrier to practice.

One of BINGO´s key objectives right from the beginning was to establish CoPs to apply a collaborative integrated approach to climate challenges. The BINGO CoPs involved researchers and key stakeholders and practitioners who are relevant to address Climate Change challenges for the local water cycles or systems. In order to embrace true knowledge transfer and bring practical knowledge and experience into the project, BINGO settled and facilitated a CoP in each research site, according to their own context specificity, guided by a common interactions (workshops) roadmap. Additionally, BINGO created dedicated virtual interaction "rooms" in its Basecamp Platform to support each site´s CoP exchanges in each native CoP languages and a "CoP room" to support interactions and exchanges between the different site CoPs in a whole global BINGO CoP.

What limitations did we find in the work of the BINGO project?

Reproducing the effects of Climate Change by modelling climate and up-following impacts are producing a huge amount of data. The ability to transfer that into "easy" understandable information for acceptance and decision-making processes is from our experience still weak. Dealing with uncertainties and probabilities for finding more dynamic adaptive measurements is an ongoing process we still have to learn.

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Why was a project like BINGO so important for the process of understanding what we are facing and to solve the so seemed unsolvable?

The process of communication and building a network between so many great experts all over Europe with their different expertise and problems helped a lot to understand which changes and regarding challenges we are facing. Because we can only solve the unsolvable together, it is important to see it from all the different perspectives and participate in. The most valuable outcomes from BINGO for the challenges we are facing already, were the motivation from working with ambitious people and coming and working together, as an European community, on our future.

7.2 About concepts, methodologies and results addressed by BINGO

Ensemble predictions: what, why and how?

Decadal predictions are – like weather forecasts – initial value problems. This means that an accurate decadal prediction or weather forecast is dependent on an accurate measurement of the state of the earth system (i.e. atmosphere, ocean, etc.). Using fundamental equations, an accurate measurement of the earth system's properties (e.g. temperature, pressure, etc.) can be used to calculate the future evolution of the earth system from this measured initial state.
Measurements of the earth system, however, possess an inherent level of uncertainty. It is simply not possible to perfectly measure the state of the earth system. When the fundamental equations are applied to compute decadal predictions (or weather forecasts), small inaccuracies in the measurement of the earth system's initial state will propagate over time to eventually produce an unreliable prediction.

To account for the inherent measurement uncertainty and how this can influence the final predictions, the so-called "ensemble prediction" technique is adopted. Here, instead of using the best estimate of the earth system's state to begin a single prediction, a large number of initial states are used to produce a large number of predictions. This set of predictions is known as the "ensemble" and the final prediction is simply the average of all ensemble members. In weather forecasting, the different initial states are typically produced by applying random perturbations to the best estimate initial state. In the MiKlip project, the different initial states for the decadal predictions are produced by simply staggering the start time of the predictions by 24 hours.

By taking the final prediction as the average of all ensemble members' predictions, the uncertainty due to inaccuracies in the measured state of the earth

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system can be greatly reduced, giving more reliable predictions. The divergence between the different ensemble members can also be used to estimate the confidence in the ensemble mean prediction: little divergence representing higher and large divergence lower confidence. Individual ensemble members can furthermore be isolated to study best- and worst-case outcomes.

Why is it important to downscale decadal climate predictions to medium-high resolution?

Water managers and decision-makers have to make decisions for the short term (2-5 years) without compromising the long term. On the other side, most adaptation measures are mostly local dependent. Regional climate models are not sufficiently detailed in space and time to support water management decisions. Decadal predictions allow for detailed prediction of the relevant climate variables decision makers need at the appropriate scale and time they need. These means that one can test and validate the existing "adaptation plans" and improve them in a timeline that fits the decision process horizon.

Can I replicate the methodologies of the project in other places in Europe?

The BINGO methodology was designed to be applied in the very distinct research sites involved in the project, all of them different in terms of climate, geography, socio-economic landscape, local governance and social connections. As a single hard methodology could not be used in such a diverse set of case studies, the BINGO methodology was developed to be flexible, allowing the work from BINGO to be adjusted according to the specific characteristics of each site, resulting in several nuances in the application of the BINGO methodology.

The BINGO project, now that it has ended, aims to serve as inspiration for other municipalities across Europe, having in mind that successfully applying the methodologies shared in this e-book requires adaptation to the local characteristics. This is why we share guidelines for specific common points in each step of the BINGO overall methodology that can be used as the basis to be replicated and adapted.

You provided adaptation measures to your research sites. Where can I find them and can I also use them in my municipality?

We developed an online portfolio of adaptation measures that have been collected and analysed in the BINGO project. This portfolio is available here. The information is focused on strategists, decision makers and policy makers in different sectors, such as water resource management, urban drainage, public water supply and agriculture. The information in the database is primarily focus on governance aspects of the measures, using the three-layer-framework that

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has also been used in BINGO.

We want to motivate all other regions in Europe to find a fitting adaptation measure for their issue – but with the awareness that each measure should serve as inspiration and be adjusted to the local specificities of the municipality which will apply them.

What were the main contributions to innovative knowledge at the Wupper research site?

BINGO gave us the opportunity to significantly improve our experience in the usage and interpretation of climate data, based on reanalysis products, decadal predictions, and climate projections. For instance, in order to capture accurately extreme convective rainfall events, fine spatial and temporal resolution are of crucial importance. Additionally, the determination of indices like SPI (Standardised Precipitation Index) and SPEI (Standardised Evapotranspiration-Precipitation Index) demonstrated to be a robust method for comparison between several data sets, where differences between bias and not bias corrected data sets were negligible. This approach can be applied to other research sites worldwide, serving as a tool which supports decision making processes for reservoir management.

How will Climate Change impact the water cycle in the Große Dhünn reservoir (Wupper research site)?

All simulated climate scenarios (decadal predictions as well as climate projections) show a negative trend in the current decade in terms of reservoir storage, where none of the data sets reach the maximum storage volume by the end of 2024. Water stress at the Große Dhünn reservoir is therefore not an unlikely scenario. On the other hand, anthropogenic influences like predicted land and water use were also considered under BINGO. This demonstrated that Climate Change alone will not influence future water availability at the Große Dhünn reservoir: while estimated land use changes for the next decade will not play a significant role in runoff generation, reservoir volume proved to be highly sensitive to different water use scenarios, based on future water demand and low flow augmentation (used for ecological flow). Thus, risk reduction measures should be implemented.

Which are the consequences of Climate Change inaction for a city like Badalona?

Results from the cost-benefit analysis preformed in Badalona have estimated that, if no adaptation measures are taken to adapt the city to the impacts derived from Climate Change, the expected annual damage (EAD) derived from urban flooding can increase in a 30% (from 1.5€ to 1.9€) considering

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direct and indirect damages and the expected annual damage derived from combined sewer overflows can represent 1.4 M€/year.

Which is the most cost-beneficial measure to adapt Badalona to urban flooding?

The Early Warning System (EWS) is the most beneficial measure among the 3 analyzed ones. Indeed, the EWS can significantly reduce flood vulnerability (not hazard), expected annual damage (EAD) and risk for limited costs. Sustainable Urban Drainage Systems (SUDS) S are the second most beneficial measure. Despite the fact that the analyzed SUDS can only slightly reduce flood hazard (not vulnerability), EAD and risk, they have lots of other socio-economic- environmental benefits (i.e., CO_2 depletion, heat island reduction, ecosystem services, aesthetic value, etc.). The structural measures proposed (addition of new inlets, sewers and retention tanks) are the least convenient from a CBA point of view because the flood EAD reduction is not high enough to compensate the high investment and annual costs of structural measures.

Which is the most cost-beneficial measure to adapt Badalona to combined sewer overflows?

SUDS are the most beneficial measure in terms of net benefit. They involve high socio-economic benefits mainly derived from the ecosystem services they provide (habitat creation, leisure/social spaces, etc.) but also from heat island reduction or air purification. On the other hand, structural measures do not provide net benefits given that the investment and operational costs are not compensated by the socio-economic benefits they provide.

What are the effects of Climate Change on the groundwater system at the Veluwe?

As less precipitation falls and more water evaporates, the groundwater level at the Veluwe decreases. One dry year has little effect on the groundwater level at the Veluwe and the discharge of streams. The high parts of the Veluwe react slowly to changes in precipitation and evaporation. In several dry years in a row, the groundwater level decreases further than usual in dry periods. Also the discharge of the brooks decrease. They can even decrease to zero discharge.

To what extent does Climate Change affect the use of groundwater at the Veluwe?

Demand for drinking water is increasing as it will become warmer. Approximately 30% of the drinking water in the province of Gelderland is produced at the Veluwe. In the event of extreme drought, other parts of the Netherlands may also want to make use of the groundwater reserves at the Veluwe.
The farmers will extract more groundwater to

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prevent damage to the crops. The growing season will also become longer, increasing evaporation and further increasing water demand.

Are there any other effects of Climate Change besides changes in the groundwater system at the Veluwe?

As the temperature rises, the Veluwe will become even more attractive as a recreational area. As a result, the demand for water increases during the summer season. The warmer climate increases the growth of algae and bacteria, affecting quality of surface water and the water systems dependent on that (streams, springs and recreational water). Also the risk of forest fires will increase.

What are the most effective measures to adapt the Veluwe to drought?

In the BINGO project, three measures have been investigated to increase the groundwater supply at the Veluwe: a ban on irrigation for farmers on the edges of the Veluwe, large-scale infiltration of surface water and the felling of coniferous forests. Infiltration of 30 million m3 of surface water per year or felling of large areas of coniferous forest appear to be the most effective measures to raise the groundwater level. Prohibiting irrigation or felling of smaller areas of coniferous forest has hardly any effect. Because the Veluwe is a large, slow-response groundwater system, large-scale measures are required.

As a water manager, which is the most important lesson learned from the BINGO project?

On behalf of Aigües de Barcelona, the company which deals with the sewerage network and the Wastewater Treatment Plants (WWTPs) of the Barcelona Metropolitan Area, I must admit that Climate Change issues were not seriously considered in the past while designing infraestructures such as sewers or WWTPs.

Due to the long lifespan of these infraestructures, both current and future conditions must be taken into account while designing. The BINGO project has shown that future climate predictions are not easy to make. Choosing both the proper numerical model and the suitable scale requires great experience and sometimes these tools are expensive and time demanding. Whatever the circumstances, the BINGO project has shown very good approaches to be considered either in Combined Sewer Overflows, CSOs (short term predictions, 2015-2024) or flooding (long term predictions, 2100), although every location would require a specific study.

Can the added value of high resolution climate models be realized without excessive computational expense?

Yes (partly). Within BINGO, a classification algorithm was developed for identifying days with an elevated

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risk of extreme precipitation at a given catchment. These days were then targeted for selective dynamical downscaling to O(1 km) resolution, reducing computational expense by over 90% and still realistically representing the extremes.

More information in:

Meredith, E. P., Rust, H. W., and Ulbrich, U. (2018) A classification algorithm for selective dynamical downscaling of precipitation extremes, Hydrol. Earth Syst. Sci., 22, 4183-4200, https://doi.org/10.5194/hess-22-4183-2018.

What is the difference between decadal predictions and climate projections?

The relatively new field of decadal climate prediction aims to simulate both the climate response to future anthropogenic forcing and the future evolution (from the present) of the climate due to internal climate variability. This differs from the approach taken in climate projections, e.g. the CMIP5 project, where the focus is on the response of the climate to anthropogenic forcing and the impacts of internal climate variability are (supposed to be) nullified via multi-decadal climate model integrations. Unlike in climate projections, the earth system models (ESMs) used in decadal prediction systems are initialized with an observed state of the climate system, i.e. ocean, atmosphere, soil, ice, etc. Skill in predicting internal climate variability on a decadal scale is derived from the long-term memory (i.e. sensitivity to the initial state) of certain components of the climate system, predominantly the ocean. As such, decadal predictions (unlike climate projections) are reliant on a high-quality initialization of the ESM for those components which exhibit long-term memory. Due to inherent uncertainty in the initial conditions, however, the best-estimate initialization can never be completely correct. Errors in the initial conditions will propagate over time, making the longer-term predictions less reliable (this is like the well-known problem in weather forecasting). To account for this inherent uncertainty, several sets of initial conditions are created by applying random perturbations to the best-estimate initial conditions. These perturbed initial conditions then form the basis for further predictions over the same time period. Together, all separate decadal predictions (often referred to as "realizations") form a decadal-prediction ensemble. The most accurate prediction will be found in the ensemble mean. For other applications, however, it may be of interest to consider the most extreme members, i.e. the members furthest above/below the ensemble mean. Which approach to take depends on the aims of the analysis and needs to be decided by each user based on their needs.

How can municipalities select adaptation measures, based on the BINGO experience?

One of the goals of the BINGO project was to select and analyse adaptation measures as part

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of an adaptation strategy. We have applied a stepwise approach to prioritize between measures. The approach relies on active participation of stakeholders which was organized, in BINGO, through Communities of Practice (CoPs) but also consultation of experts beyond the CoPs. The BINGO guidelines "Prioritisation between adaptation measures" can be used to help municipalities qualify and select adaptation measures suitable to their specific context. The six steps of the approach include:

- Create portfolio of potential adaptation measures
- Select relevant measures based on risk analysis and stakeholder preferences
- Multi-Criteria-Analysis (1): Develop a set of socio economic indicators to score the selected measures
- Multi-Criteria-Analysis (2): Score selected measures on socio economic criteria
- Analyse adaptation measures on social justice
- Analyse adaptation measures for governance needs using the three-layer-framework

What is a "Multi-Criteria-Analysis" and why can be it applied to adaptation measures?

A Multi-Criteria-Analysis is a method to evaluate options (such as measures) using a broad range of indicators, related to socio-economic or other (e.g. environmental) factors. In this way, the wider socio-economic effects and side effects of adaptation measures can be assessed to a broader extent than looking at costs and the direct effect on risk reduction. A Multi-Criteria-Analysis can also be used to analyse effects that are difficult to quantify (e.g. acceptability or environmental side effects). To perform a Multi-Criteria-Analysis, a set of indicators/criteria must be selected to score the measures against. Which indicators/criteria are most suitable is very dependent on local circumstances, therefore this step can best be performed at the level of the research site, involving local stakeholders.

What is a "Social justice analysis" and why was it applied to adaptation measures in BINGO?

Social justice is considered an increasingly important topic in Climate Change adaptation. Therefore, to support decision making on adaptation it is important to take this issue into account. In the social justice analysis, the focus lies on the distribution of costs/ negative impacts and benefits of the adaptation measures to different actors or groups in society. Social justice can be analysed by answering a set of questions for each adaptation measure.

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What is a "Governance needs analysis" and why was it applied to adaptation measures in BINGO?

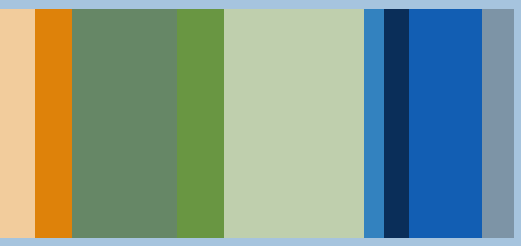
The governance analysis is useful to prepare a successful implementation of measures. "Governance needs" are the governance requirements that need to be met to be able to implement the measure, such as knowledge requirements, administrative requirements and legal-operational requirements. The governance analysis is based on a three layer framework which has been developed by the Water Governance Council to assess the policy and governance situation in light of Climate Change adaptation.

Why is a cost-benefit analysis (CBA) so helpful for decision making in Climate Change adaptation?

A CBA helps the researcher, consultant or engineer to focus and point out the main expected benefits as well as necessary resources input to implement an adaptation measure. Furthermore, it serves as a good tool to compare alternative solutions. One of the main advantages is that results of the analysis are presented in one, easy to read key figure for the decision maker(s). It also delivers information necessary to organize the financing of final measures and thus is a valuable tool to speed up the implementation after decisions are taken for specific Climate Change adaptation in water systems.

In which decision cases is a cost-effectiveness analysis (CEA) useful for decision makers and stakeholders?

A CEA is a fitting framework, once many different risk reduction solutions are technically feasible with a comparable output. This is especially helpful in situations, where it is hard to express the benefit in monetary terms, but where a non-monetary indicator, eg. a technical indicator can be used to express the benefit of a measure (i.e. the risk reduction effectiveness), this can be e.g. reduced combined-sewer-overflow in m^3 or additional available raw water in m^3. The CEA can help to identify the low-cost solution among a set of fitting measures. Overall the CEA is a fitting tool integrating multiple disciplines in one framework: Engineering and economic perspectives to characterize measures, hydrologic and climatic perspectives for the risk and effectiveness of adaptation measures. This is quite useful for a thorough Climate Change adaptation of water systems.



8 FUN AND GAMES

8 Fun and games

8.1 Representation/ performance

8.1.1 Background and Motivation

During these almost 5 years of proposal preparation and work, there was the opportunity for an amazing collection of pieces of knowledge and understanding. The variety of activities included thorough scientific research, Climate Change and water modelling, risk assessment and establishing Communities of Practice (COPs) with stakeholders within the 6 countries that were part of BINGO. These range of activities provided scope for acknowledging a baseline truth: dealing with adaptation in Climate Change is complex and requires that all of society, in general, is well informed and is available to move forward. Putting it in other words: "Climate Change calls for conscious cooperation"!

We are all well acquainted with the fact that arts, music, games, movement and other kinds of expression are privileged ways of conveying messages that are assimilated both by the performers, participants and the audiences.

Broad materials are meant to be used as they are, or as an inspiration, adapting to the context of use. The scripts can be used in different levels of schools, associations or other organisations dealing with people from different ages.

They are appropriate for young children, teenagers, adults or seniors. They can be adapted to various spaces and time durations. All are invited to use your creativity and fit the scripts to your context!

We do expect that this contribution can be widely used and create moments of cooperation, entertainment and new understandings and insights into the power of **knowledge**, **communication** and **collaboration**.

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8.1.2 Musical Representation

This Musical Representation was created in five acts, to be performed by at least seven people.
The representation includes use of three linen/cloths with different colours. They symbolise three hazards associated with Climate Change, namely, blue for floods; brown for droughts, and red for increased temperature/ heat waves.
It also proposes the use of paper boxes to materialise the words "Knowledge", "Communication" and "Cooperation". According to the number of people representing, it can be either a box for each word (total of three boxes) or a box per syllable, meaning a total of fourteen boxes (three for Know-le-dge; five for Co-mmu-ni-ca-tion, and six for Co-o-pe-ra-ti-on). The boxes will be used for Acts II to IV.

When the performance place/ room allows, some of the Acts include the projection of a background slide setting a theme or sentence; these slides can be replaced by a background voice. Each act contains the description of scenic and light details.
These are the five Acts of the Musical representation created by BINGO, called:

Climate Change calls for conscious cooperation

Act I - Prologue

Act II - Knowledge

Act III - Communication

Act IV - Cooperation

Act V - Closure

Act I - Prologue

Settings

- The 3 or 14 boxes are scattered around the floor of the scene
- The 3 cloths are also displayed around
- Music and light (if possible) follow the representation

8 Fun and games

Representation guidelines

The performers (at least 3) take the cloths and play with them, dance, take them around... First the red and brown together (droughts and high temperatures) are the protagonists then they are changed to the blue one, showing the unexpected and high variation of these events nowadays.

At the same time while such changes are taking place, there are people walking around - these characters may be stereotypes of the student; the children; the teacher; the executive; the old man, etc. They show how distressed they get by the heat and dry weather and then by the flood events. They walk around and move the boxes, just showing they do not know what to do or how to react.

Settings

- Low light. The Prologue ends with the projection of a background slide saying "What is going on?"

Act II - Knowledge

Settings

- The boxes are scattered around and at the back of the scene. The players start holding together the 3 linens

Representation guidelines

Represent people dancing with the 3 linens/ cloths together, not knowing what to do with them, getting trapped, falling down and getting entangled and hidden by them. Then, someone has an idea: they separate the linens and place the 3 cloths clearly apart in the floor.

With a dance/choreography, some people find the boxes (or the only box) to construct the word "Knowledge" placing it at one of the sides of the scene (right or left hand side).

At the end of this Act, people move apart, giving the back to each other. One or more of the players stay by the boxes as if he/she/them were the only owners of "Knowledge".

Act III - Communication

Settings

- The act starts from where ended Act II
- The 3 linens are separately set on the floor
- The box (boxes) for "Knowledge" stand(s) at one of the sides of the scene
- The boxes for "Communication" and "Cooperation" are still scattered around/ at the back of the scene/stage.

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Representation guidelines

Represent people moving as single individuals, not looking neither communicating with each other. Some of them can stand in front of each other as if talking at the same time and not caring about listening. The movements are not synchronised.

People "hold" to the knowledge box/boxes and fight over them. Some get close to the blue linen and show concern for floods; others do the same with the other linens, metaphors for droughts and high temperatures.

As the scene develops, bit by bit, some people start taking the time to listen to each other. At the end, they bring together the "Knowledge" box/boxes to the middle of the scene, take the "Communication" box/boxes as well, and place them near the "Knowledge". All together, they move/dance very synchronised and with happy smiles around the boxes. At the end, they move the boxes (except for cooperation) to one of the sides (right or left hand side).

Act IV - Cooperation

Settings

- Act IV starts from where Act III ended
- The 3 linens are separately set on the floor
- The boxes for "Cooperation" are still scattered at the back of the scene/stage
- The boxes for "Knowledge" and "Communication" are side by side at the left or right hand side of the scene/stage.

Representation guidelines

The Act starts with 3 groups of people, each one around one of the linens. In each group people talk to each other, and synchronize their movements. Then everyone starts looking around to the other groups. One person from one of the groups move to peep at another group then comes back to his/her original group. This movement is repeated by other people from other groups, and the overall motion ends with people standing together in a circle, around the 3 linens. They all dance showing high level of synchronisation, happiness and engagement with the group.

The Act ends with some people getting the box/boxes to place the word "Cooperation" close to the other two: "Knowledge" and "Communication".

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Act V - Closure

Settings

- Act V starts from where Act IV ended There is a background slide projection or voice speaking the words: "Climate Change CALLS FOR CONSCIOUS COOPERATION"
- The boxes for "Knowledge", "Communication" and "Cooperation" are visible placed on the stage/scene
- It is important to select a very joyful and rhythmic music for this end!

Representation guidelines

Everyone is dancing in a much synchronised way, a powerful choreography. If possible, they should wear the same hat or T-Shirt to make clear they are a team. They invite people from the audience to join them.

The End!

8.1.3 Role Playing

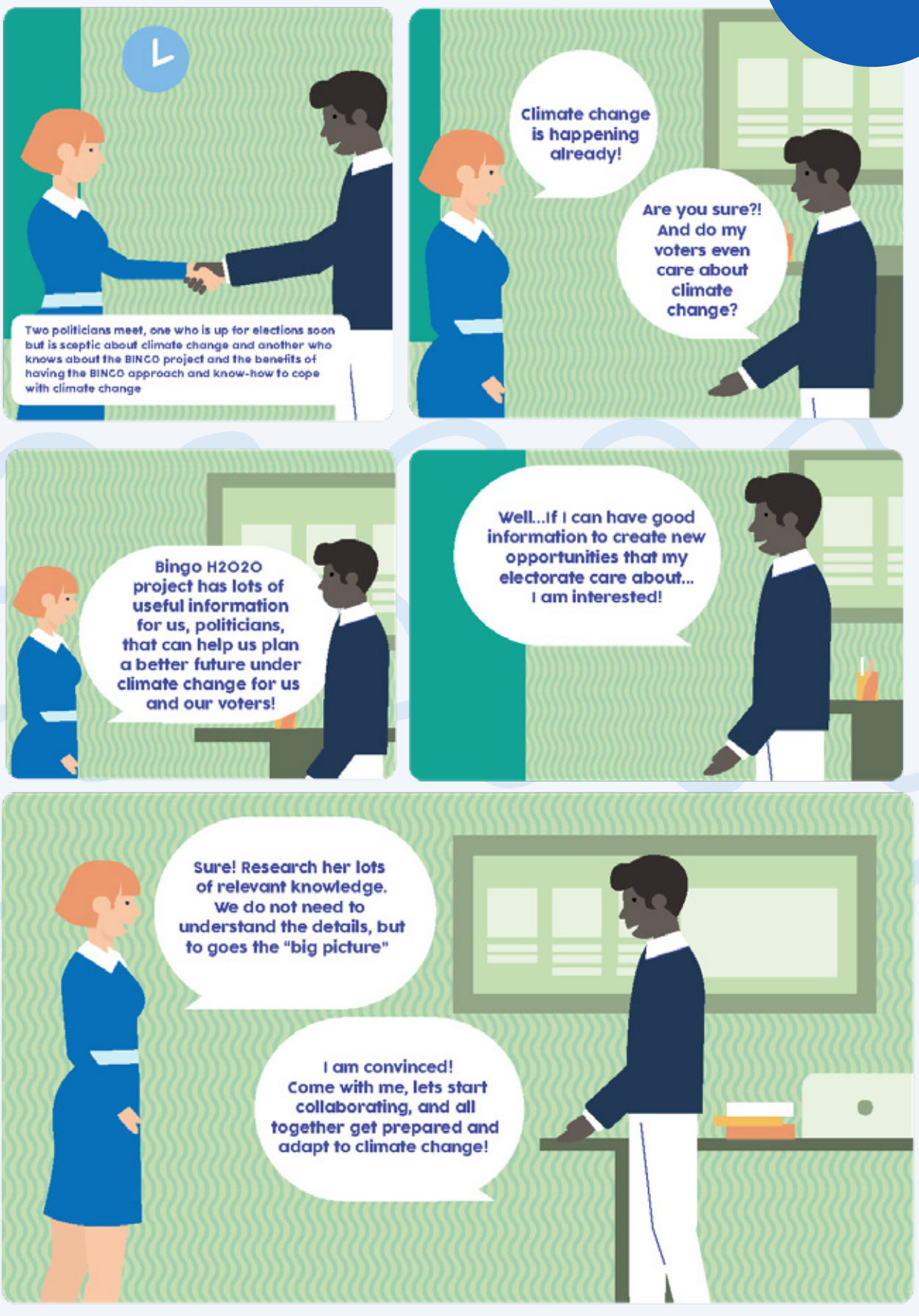
As a new way to communicate the project's results, the BINGO team has developed 2 thematic performances involving very different types of stakeholders:

Two politicians - a conversation between 2 politicians, one who is up for elections soon but is sceptic about Climate Change and another who knows about the BINGO project and explains the benefits of having the BINGO approach to Climate Change in their area.

Farmer - tells a story of a young farmer who started having issues with the irrigation of her olives, until she was introduced to the BINGO project by her grandfather and decided to create a Community of Practice in her own village. These performances were presented at the Final Project Meeting, to all of the project partners, and at ECCA 2019.

Performance to disseminate BINGO results to Politicians

Click here for the entire script



Performance to disseminate BINGO results using as "trigger" the agriculture sector

Click here for the entire script

8 Fun and games

Download game here!

8.2 BINGO game for CoPs

The BINGO team has developed a game of bingo about the BINGO project that has been applied in several dissemination opportunities. Actually, the BINGO project game uses cards with sorted numbers that are distributed by the participants and these numbers are sorted in a random way by a game pivot till someone fulfils its card, just like a traditional bingo game. But to enhance a cross-learning ambiance between participants, these numbers are associated with to questions (that are made by the game pivot) and to the correspondent answers (that are in the participants cards). So, the pivot has a coffee cup were each number and question is glued to an icecream stick put in it with the numbers hidden in the bottom of the cup, He/she randomly picks a stick and first reads the question (telling the number only afterwards) and participants are teased to find the answer on their cards. The one who found the right answer and the correspondent number on his card is asked to read it out loud to everyone.

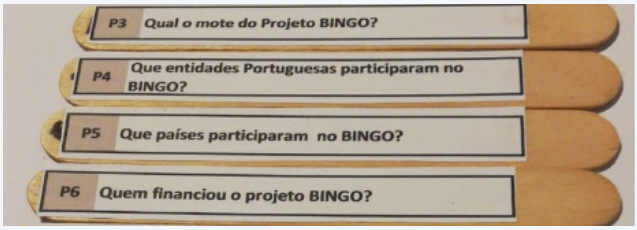


Figure 11: Icecream sticks with questions (used at a dissemination event in Portugal)

The game is played by following these instructions:

- Each player has a card with 9 answers, each answer corresponding to a number;

Figure 12: Example of a card

Figure 13: Participant playing

- The host of the game would take a question out of the cup and ask, also saying the number of the answer;

Figure 14: BINGO game pivot (from LNEC) asking a question to participants at ECCA 2019

8 Fun and games

- The person who had the number of the answer would read the answer out loud;

Figure 15 - Participant reading an answer

- Once a player would complete their whole card, they would say "BINGO";
- The host would finish the game and offer a prize to the winner.

Figure 16: Playing BINGO WHO at the project booth in ECCA 2019

8.3 BINGO WHO?

BINGO WHO? is a game of questions with multiple answers that our team organised to disseminate the project in a fun format. It has several questions related to BINGO, and issues of water and Climate Change.

Want to play? Discover the right answers (A, B or C) to each of the 16 questions!

8 Fun and games

	Question	A	B	C
1	What was the key to project BINGO's success?	Working independently	Collaboration	Focus only on the scientific outputs
2	One of the major transferable results of BINGO was the Advice on...	Independent Management in Climate Change Mitigation	How To Make A Great Game For A Conference	Collaborative Management in Climate Change Adaptation
3	Is the BINGO climate data available to everyone?	Yes, all info at the BINGO website	No	Yes, if you pay, all info at the BINGO website
4	What does BINO downscaling methodology reduce in climate simulation models?	Simulation accuracy, by 10%	Resolution, by 45%	Computational expense, by 90%
5	Did BINGO hydro models apply to every research site?	No	Yes, after tailoring, set-up, calibration and validation to local characteristics	Yes
6	How did BINGO hydro models adapt to each research site?	By directly involving stakeholders in the model set-up and application	By trial and error approach	By working with the scientific team to try to
7	What type of activities did BINGO focus on?	Climate Change impacted activities	Water dependent socio-economic activities	Water sports
8	What did the risk assessment methodology in BINGO address?	The risks to the surf industry	The key questions to better cope with impact of Climate Change	The impact of Climate Change on agriculture

8 Fun and games

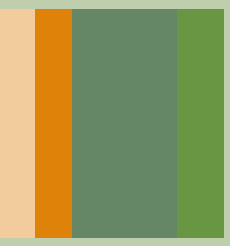
9	Where is the BINGO portfolio of adaptation measures?	In a library in Brussels	Online	In our hearts
10	Can anyone use the portfolio of adaptation measures?	Yes	No, only decision-makers	Yes, if you visit the library in Brussels
11	How did BINGO helped identify appropriate measures for the Climate Change risks?	With an app	Lengthy analysis of the overall context of the local economies	Socio-economic cost benefit analysis and governance analysis
12	According to BINGO's methodology, who must the prioritisation between long list of adaptation measures involve?	All relevant stakeholders in all relevant sectors	The policy makers	People who agree with each other
13	What does CoP mean in BINGO?	Communities of Practice	Collaboration of People	Coordinated own Project
14	Which one is a key aspect of a functioning CoP?	Lead and make a strict work plan	Allow everyone to lead and go with the flow	Designate a CoP facilitator & design a roadmap
15	How many exploitable results did BINGO produced?	2	8	6
16	How did BINGO identify the exploitable results?	Through a vox-pop	Through a collaborative canvas exercise, involving all project members	Through the hard-work of one person

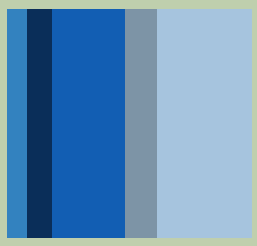
8 Fun and games

Find the answers below...

Answers to the **BINGO WHO?** questions:

8	B	16	B
7	B	15	B
6	A	14	C
5	B	13	A
4	C	12	A
3	A	11	C
2	C	10	A
1	B	9	B





9 RESOURCES

9 Resources

Project reports

Covering all steps and outputs of our project, our reports will tell you the detailed story of the work developed in BINGO. They describe in detail all the results and methodologies.

Guidelines

If you read this e-book, you already know about it – our guidelines are a key output of the project that can help you implement any of the methodologies developed by BINGO. From applying hydro models to implementing successful communities of practice, you can find step-by-step guides on how you can replicate our methodologies!

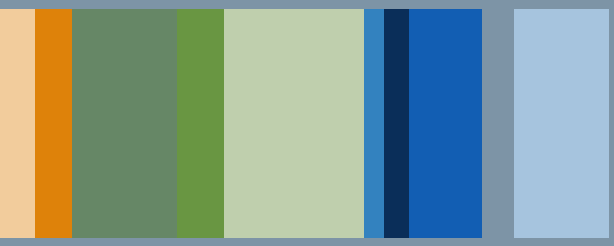
Publications

From these 4 years of work, many reports and scientific publications were produced and published/presented, covering all the main topics of the project:

- Climate predictions and downscaling to extreme weather
- Integrated analysis of the water cycle
- Assessment of the impacts of extreme weather events
- Developing risk treatment and adaptation strategies for extreme weather events
- Ensuring Excellence and Actionable Research

Check them out here!

BINGO
a better future under
CLIMATE CHANGE



THE BINGO PARTNERS

The Bingo Partners

THE BINGO PARTNERS

The BINGO consortium includes 20 European partners located in six countries: Portugal, The Netherlands, Germany, Spain, Norway, and Cyprus. It comprises eight research and innovation partners (LNEC, KWR, IWW, Aqualogy, NTNU, InterSus, FuB, and CYI), and stakeholders from different decision levels, including seven policy bodies (CIMLT, DGADR, AMB, AjBadalona, Prov. GLD, Bergen K and Wupperverband), two utilities service companies (EPAL, AGBAR), and three organisations with a sectorial focus (SPI, I.A.CO, and Vitens). Check them out!

LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL (PORTUGAL)

http://www.lnec.pt/

The National Laboratory for Civil Engineering (LNEC) is a public research institute devoted to Science, Technology and Innovation in Civil Engineering and related fields.

LNEC was the Project Coordinator and the Leader of Work Package 1: Coordination, management and IPR and Work Package 4: Assessment of the impacts of extreme weather events.

KWR WATER B.V. (NETHERLANDS)

http://kwrwater.nl/

KWR is the Dutch research institute for the drinking water sector.

KWR was the Leader of Work Package 5: Developing risk treatment and adaptation strategies for extreme weather events.

IWW WATER CENTER (GERMANY)

http://iww-online.de/en/

IWW is a private non-profit research and consultancy institute founded by German water companies and water associations.

IWW was the Leader of Work Package 3: Integrated analysis of the water cycle.

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AQUATEC, PROYECTOS PARA EL SECTOR DEL AGUA, S.A.U. (SPAIN)

http://suez-advanced-solutions-spain.es/

Aquatec (Suez Advanced Solutions, Spain) is a water and environmental technology company.

Led the Risk Identification task and provided a large contribution in the implementation of 1D/2D urban floods modelling and CSO and water quality impact on receiving media.

NORGES TEKNISKNATURVITENSKAPELIGE UNIVERSITET NTNU (NORWAY)

https://www.ntnu.edu/

The Norwegian University of Science and Technology (NTNU), is a merger of the previous Norwegian Institute of Technology (NTH), established in 1910 and the University of Trondheim.
NTNU was the Leader of Work Package 6: Ensuring Excellence and Actionable Research

INTERSUS - SUSTAINABILITY SERVICES (GERMANY)

http://www.intersus.eu/

InterSus is a small environmental policy consultancy (SME) working for various national and international clients (including the European Commission, various UN agencies, the European Environment Agency, World Bank, OECD, WWF, Environment Ministries etc.).

InterSus was a key contributing partner to Work Package 5: Developing risk treatment and adaptation strategies for extreme weather events.

FREIE UNIVERSITAET BERLIN (GERMANY)

http://www.fu-berlin.de/en/

The Freie Universität Berlin (FUB) is one of the largest universities in Germany, awarded the status of excellence by the German Research Funding organization, DFG. The main research areas of the Institute of Meteorology (IfM) are weather forecasting, climate research, environmental impacts, remote sensing and the stratosphere.

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FUB was the Leader of Work Package 2: Climate predictions and downscaling to extreme weather.

SOCIEDADE PORTUGUESA DE INOVAÇÃO - SPI (PORTUGAL)

http://www.spieurope.eu/

Sociedade Portuguesa de Inovação was created in 1997 as an active centre of national and international networks connected to the innovation sector with a mission being the management of projects that foster innovation and promote international opportunities. SPI was the Leader of Work package 7: Dissemination, communication and exploitation.

THE CYPRUS INSTITUTE LIMITED (CYPRUS)

http://www.cyi.ac.cy/

The Cyprus Institute (CyI) is a non-profit research and educational institution with a strong scientific and technological orientation, founded in 2005. CYI led the high-resolution downscaling task, the field investigations at the research sites, the actionable labs and the Cyprus Research Site.

I.A.CO ENVIRONMENTAL AND WATER CONSULTANTS LTD (CYPRUS)

http://www.iaco.com.cy/

I.A.CO Environmental & Water Consultants Ltd (hereby referred to as I.A.CO) specializes in provision of consultation services in the sectors of environmental and water engineering and management. I.A.CO was a key contributor for the Cyprus Research Site.

EMPRESA PORTUGUESA DAS ÁGUAS LIVRES, SA - EPAL(PORTUGAL)

http://www.epal.pt/

EPAL is the largest and oldest water utility in Portugal, supplying drinking water to around

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three million people in 35 municipalities, including the city of Lisbon.

As the water utility that supplies Lisbon and 34 other municipalities, EPAL was mainly involved in WP3 (water system characterization, providing data for modelling and assessing results), WP4 (risk assessment, providing the necessary inputs from the company and validating the results), WP5 (validating adaptation strategies and performing cost benefit analysis), WP6 (participation in sharing awareness and knowledge activities), WP7 (participation in dissemination events).

COMUNIDADE INTERMUNICIPAL DA LEZIRIA DO TEJO - CIMLT (PORTUGAL)

http://www.cimlt.eu/

CIMLT is an association of 11 municipalities of the region 'Lezíria do Tejo', with over 20 years of existence.

As the supramunicipal stakeholder for the Tejo research site, it was mainly involved in WP3 (providing data and assessing results), in WP4 (validating impacts) and in WP5-WP7 (defining risk management strategies in close collaboration with stakeholders).

AJUNTAMENT DE BADALONA (SPAIN)

http://badalona.cat/

The city council of Badalona is an organization dedicated to build a common future, ambitious city that extends quality of life and citizen welfare.

As the municipal stakeholder for the Badalona research site, it was mainly involved in WP3 (providing data for modelling, assessing results), WP4 (validating impacts) and WP5 (defining risk management strategies in collaboration with other stakeholders)

AIGUES DE BARCELONA, EMPRESA METROPOLITANA DE GESTIO DEL CICLE INTEGRAL DE L'AIGUA SA (SPAIN)

http://www.aiguesdebarcelona.cat/ca/web/web-aguas-de-barcelona/inicio

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Aigües de Barcelona, Metropolitan Company of Water Integral Cycle Management was created in July 2013.

As the company in charge of the operation and management of the WWTP affecting Badalona research site they were mainly involved in WP3 (providing data for modelling, assessing results), WP4 (validating impacts) and WP5 (defining risk management strategies in collaboration with other stakeholders)

VITENS NV (NETHERLANDS)

http://www.vitens.nl/english/

Vitens is the largest drinking water company in the Netherlands.
As such, it was mainly involved in the Dutch Research Site experiments in WP3. The BINGO activities took place within one of the water abstractions areas of VITENS. Vitens was both end user and problem owner within the BINGO project.

WUPPERVERBAND (GERMANY)

http://www.wupperverband.de

The Wupperverband is a non-profit water association based on public law, responsible for the water management in the 813 km² catchment area of the river Wupper.
As main end user (in form of a non-profit oriented water management company based on public law) for the Wupper research site, it was mainly involved in WP3 (data preparation for modelling, model application and development, field work, result analysis), WP4 (validating impacts) and WP5 (defining risk management strategies in collaboration with other end users).

DIRECÇÃO-GERAL DE AGRICULTURA E DESENVOLVIMENTO RURAL - DGADR (PORTUGAL)

https://www.dgadr.gov.pt

DGADR is a branch of the Ministry of Agriculture and Sea of the Government of Portugal which

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focuses on forestry and rural development.
As a national level policy body, it was mainly involved in WP3 (providing data and assessing results), in WP4 (validating impacts) and in WP5-WP7 (defining risk management strategies in close collaboration with stakeholders).

AREA METROPOLITANA DE BARCELONA (SPAIN)

http://www.amb.cat/

The Barcelona Metropolitan Area (AMB) is the public administration of the metropolitan area of Barcelona which includes 36 municipalities (Badalona also).
As the supramunicipal stakeholder for the Badalona research site it was mainly involved in WP5 defining risk management strategies in collaboration with other stakeholders

GELDERLAND (NETHERLANDS)

http://www.gelderland.nl/

The main tasks of the province of Gelderland are related to environmental policy, environment, planning and the rural area.
Provincial Governmental organisation is the local decision-maker for the Veluwe area and the research site is part of the province. As such, it provided for research sites in nature reserves and disseminated project results to local partners.

BERGEN KOMMUNE (NORWAY)

https://www.bergen.kommune.no/

Bergen City Agency for Water and Sewerage Works is part of Department of Urban Development, Climate and Environmental Affairs in the City administration.
As the municipal stakeholder for the Bergen research site, it was mainly involved in WP3 (providing data for modelling, assessing results), WP4 (validating impacts) and WP5 (defining risk management strategies in collaboration with other stakeholders).

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with special mentions to:

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FILMESDAMENTE

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