IMPETUS

Turning climate commitments into action

ZEELAND - RIJNMOND

Innovation Package for adaptation and resilience

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Atlantic demo-site

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ABOUT THIS DOCUMENT

The Impetus project

The EU-funded IMPETUS project (2021-2025) helps accelerate Europe's climate adaptation strategy and meet the European Union's ambitions to become the world's first climate-neutral continent by 2050. The objective is to turn climate commitments into tangible, urgent actions to protect communities and the planet.

Central to the IMPETUS project are the Resilience Knowledge Boosters (RKB), an innovative approach to combine the voice and experience of local and regional communities with the power of digital tools. In this way, policy-makers, businesses, citizens and other stakeholders can explore climate change evidence together, share information, learn, test ideas and co-create knowledge, discover which actions could constitute the best paths towards climate adaptation, and so contribute to decision making and policies.

IMPETUS has demonstration sites in 7 European biogeographical regions. Here, multidisciplinary teams and local stakeholders work together to shape adaptation by testing diverse solutions for the local impacts of climate change and exploring alternative pathways for risk reduction and transformative change.

The innovation packages

Innovation packages are built on major IMPETUS results achieved at demo-site level. They are composed of three blocks:

1. RKBs and their digital dimension for engaging stakeholders and boost knowledge for developing a long-lasting territorial resilience.
2. Adaptation pathways, to explore alternative sequences of measures to address specific climate risks at the regional level.
3. Portfolio of climate adaptation solutions, to learn from alternative adaptation options, tested or discussed across the project, and evaluated through a common set of criteria.

The objectives are:

- To present an organised synthesis of results achieved at demo-site level within the IMPETUS project.
- To facilitate mutual learning among demo-sites by comparing different solutions to face various climate risks.
- To facilitate replication and upscaling.
- To highlight major limiting or success factors that hinder or enable the progress toward adaptation and resilience.

Key concepts: Innovation and Transformation

The "innovation component" of innovation packages is related to:

- The incorporation of transformational approach: adaptation that changes the fundamental attributes of a social-ecological system in anticipation of climate change and its impacts (IPCC, 2022; Cools et al., 2025).
- The inclusion of new technologies and tools.
- The inclusion of non-structural solutions (governance, finance and knowledge) as enabling factors to implement adaptation interventions.

INNOVATION

1. Adopting a transformational approach to adaptation.
2. Working with data-driven and digital technologies.
3. Proper consideration to enabling conditions for adaptation.

TRANSFORMATION

1. Scope of change (e.g. holistic, cross-sector, systemic)
2. Impact of change (e.g. governance, behaviour, socio-ecologic systems)
3. Depth of change (e.g. path shifting, path restructuring, innovative)
4. Temporality of change (e.g. future looking, long lasting)
5. Inclusivity (e.g. participatory, equity)

Reader's guide

This document provides an overview of the climate risks in the region and a synthesis of the knowledge, tools and solutions produced, tested or analysed in the framework of the IMPETUS project. After the section presenting the climate risks, the document is organized following the three building blocks of the Innovation package: RKBs, Adaptation Pathways, and Portfolio of Solutions. Each block includes a synthesis of main results achieved during the project, followed by a 3-angle evaluation proposed by demo-site leaders after extensive consultation with stakeholders:

- Exploitation potential for further boosting knowledge and adaptation in the region.
- Major gaps and needs to translate ideas into concrete commitments.
- Potential for fostering transformational adaptation.

Expert judgment was used to score the evaluation elements using a 1 to 5 scale.

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THE CLIMATE RISKS OF THE REGION

The Province of Zeeland and the Rijnmond Region are located in the western Netherlands. This coastal area consists of islands and peninsulas, with a significant portion of Zeeland covered by water. Situated within multiple transboundary river systems, including the Scheldt, Meuse, and Rhine, it is home to two extensive estuaries. The region includes the city of Rotterdam, home to Europe's largest port and industrial cluster, located in Rijnmond – mouth of the Rhine.

Heat stress

Despite the cooling effect of the sea in the region of Zeeland, the risk of heat stress has become a growing concern.

The effects of prolonged heat, which can cause headaches, dizziness, insomnia and other health issues, and even death, specifically affect elderly and other vulnerable people. Excess temperatures also affect general comfort and liveability of cities. Water quality can be reduced, both for drinking and swimming, and infrastructure can be affected. Buildings and concrete surfaces trap heat, potentially leading to damage, and release it during the night, keeping temperatures warm. In recent years, record-breaking summertime temperatures have been recorded in the. With global temperatures rising, such extreme weather events will occur more often, and for longer periods. Prolonged high temperatures, with warm nights as well as hot days, can cause heat stress and related health issues, especially in urban areas Netherlands.

Flooding

Both Zeeland and Rijnmond lie at or below sea level, making them highly vulnerable to flooding and sea level rise. Protections such as sea dikes and storm surge barriers have been constructed to protect the region, but flooding still occurs and it is expected to worsen, due to climate change. As the changing climate is affecting the interplay between rainfall, river levels and sea storms, local flood risks are increasing. Water levels could rise significantly, even in populated areas, with potentially massive impacts for large urban metropoles as Rotterdam Infrastructural adaptation measures as storm surge barriers are in place and effective in reducing the change that high water reaches the city. But to minimise the impact of flood when they do occur, urban climate adaptation strategies are also needed. As flood protection strategies shifts from hard measures to more integrated and sustainable solutions, new and more detailed information is needed on current flood risks.

A PLATFORM TO EXCHANGE AND BOOST KNOWLEDGE

Content

The RKB (Resilience Knowledge Booster) web platform presents and explains the regional challenges related to the management of flood risk and heat stress and helps exploring possible solutions in the perspective of climate change. The Solutions section of the platform includes the Heat Awareness System, the Decision Support System for Flood Management and the Decision Support Tool for Industrial Decarbonisation.

The *Adaptation Pathways* section includes a conceptual model for heat stress (Impact chain) showcasing how hazard, exposure, and vulnerability elements interact to generate the risk for public health, wellbeing and economic prosperity. Navigable maps with alternative Adaptation Pathways able to mitigate this risk are then proposed. In the section *Insights* it is possible to download the Innovation Packages report including the present document.

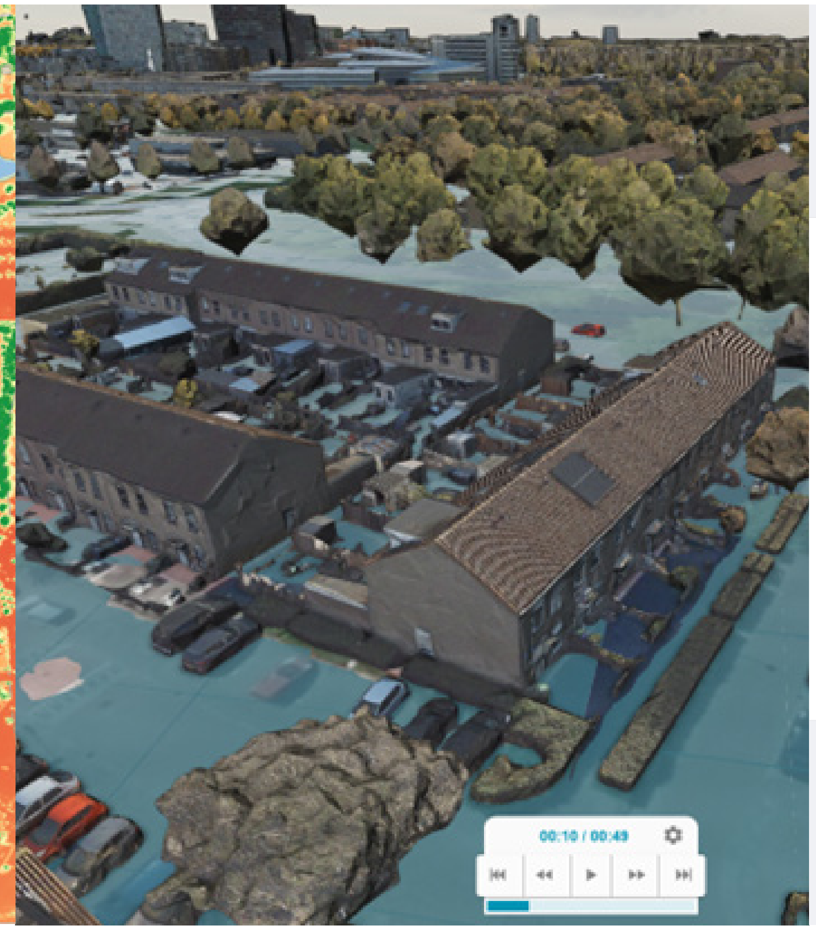
https://impetus.mantisims.gr/knowledge-boosters/atlantic/

HEAT AWARENESS SYSTEM

An online Awareness System integrating complex heat stress analysis within a 2D Digital Twin. It can identify heat stress hotspots at high resolution and assess the impact of various adaptation interventions to support data-driven decision-making through scalable, cloud-based technology.

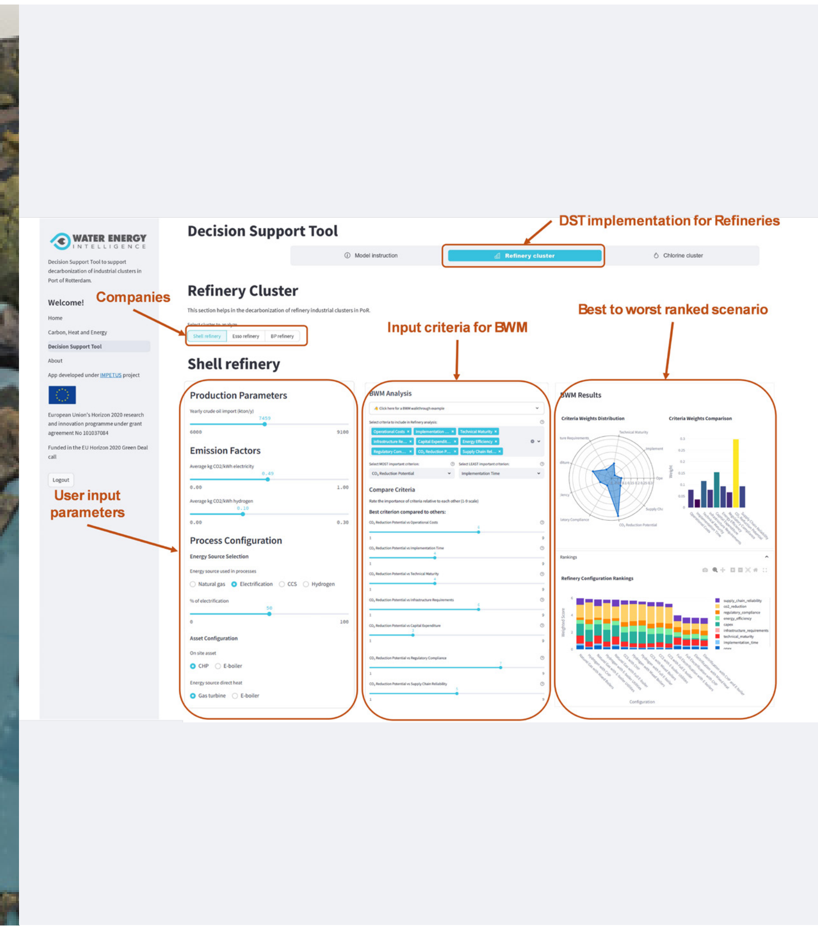
DECISION SUPPORT SYSTEM FOR FLOOD MANAGEMENT

An online Decision Support System (DSS) integrating high-resolution flood simulations within a 3D Digital Twin. It helps identify local flood risks and enables rapid analysis of adaptation measures to support decision-making through scalable, cloud-based technology and advanced visualisations.



DECISION SUPPORT TOOL FOR INDUSTRIAL DECARBONISATION

An online Decision Support Tool (DST) that models and compares decarbonisation scenarios for industrial clusters, helping to identify optimal strategies for future developments. It can quantify CO_2 reduction potential, assess financial and energy impacts, and rank alternatives based on specific priorities.



RKB - Exploitation potential

STAKEHOLDERS INTEREST

score 3/5

MAIN STAKEHOLDERS INVOLVED

Academia, Industry and Economy, State government and policy, uninformed citizens

The main stakeholders belong to Academia (HZ University of Applied Sciences, TU Delft), Industry and Economy (Rotterdam Port, Shell, Tenne T), State government and policy (Municipality of Rotterdam, Province of Zeeland, Ministry of Water and Infrastructure, Ministry of Economic Affairs) as well as uninformed citizens.

FEEDBACK FROM STAKEHOLDERS

The solutions presented in the RKB received relevant interest, with specific reference to the decision support systems for heat and flood management. Most of the positive feedback concerned the low-complexity **visualization** of climate risks, which made them easy to understand and provided clear insights. This helped stakeholders see the effects of climate risks and assess the effectiveness of adaptation measures. Effective visualization also supported communication with citizens. The RKB was presented to stakeholder in a non-finalised version, not mature enough to demonstrate its full potential. This limited the capacity of stakeholders to provide a thorough evaluation. However, co-creation with stakeholders was viewed positively.

STRENGTHS

score 3/5

A POWERFUL TOOL TO VISUALIZE ADAPTATION OPTIONS AND PROVIDE ACTIONABLE KNOWLEDGE

RKB DIGITAL DIMENSION COMPONENT	SCORE
Visualisation (layout, images, graphic design)	4
Knowledge content (quality and type of information displayed)	4
Interactive functionalities (animations, customised navigation, dashboards)	3
Feedback collection tools (pools, chats)	2

OPPORTUNITIES FOR RKB USE

score 3/5

The RKB helps municipalities to make better-informed decisions on climate risks.

Promising opportunities for commercialising the solutions presented in the RKB are emerging. Multiple local (pilot) projects run by municipalities in the region have been using at least one of these operational solutions. An example is the municipality of Leiden, which is actively testing its new spatial developments with the Heat Awareness System. Another potential opportunity is connecting to the CoolCities project (Interreg North Sea EU-funded project), involving the Municipality of Arnhem. By integrating the digital components developed within IMPETUS, the solutions could be extended beyond the project and tested in an international context.

RKB - Gaps & needs

CHALLENGES FOR PLANNING AND DECISION MAKING PROCESS

SECURING FINANCE AND GOVERNANCE

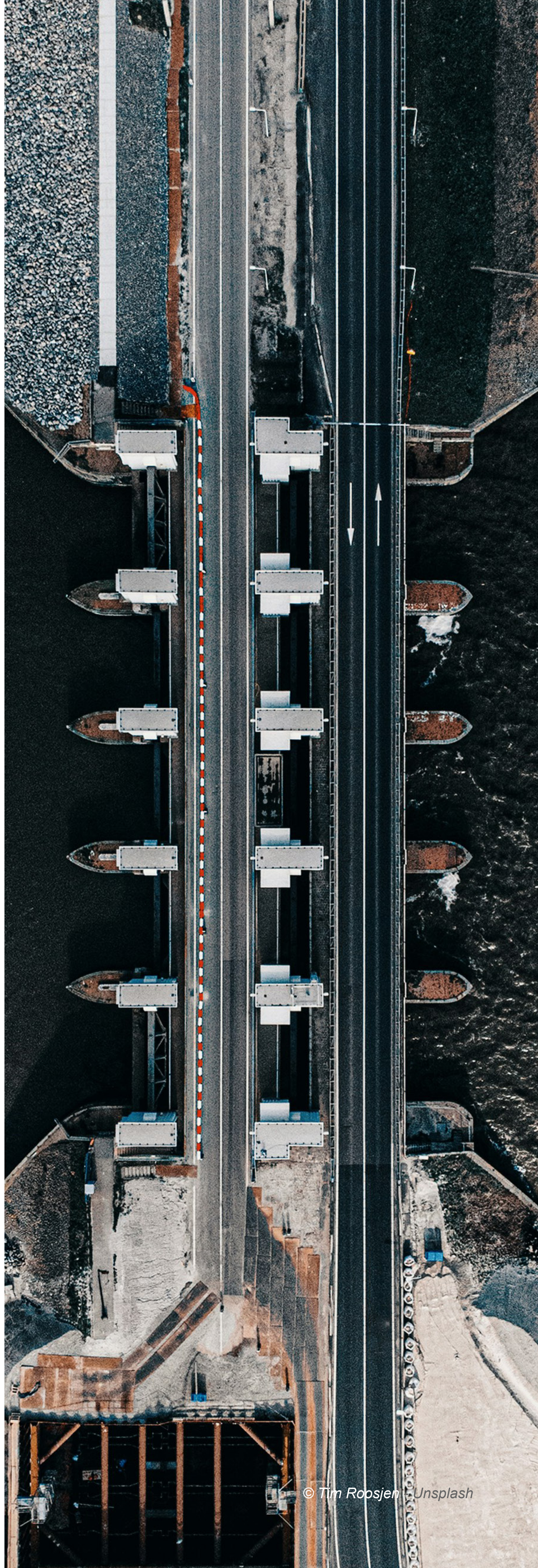
- The key challenge is to move from risk analysis to planning and implementation of concrete adaptation measures.
- Economic resources and efficient governance systems are needed to make this transition possible.

PRIORITY	CHALLENGE
1	Finance challenges
2	Governance challenges
3	Capacity challenges (ability and motivation to use knowledge for action)
4	Knowledge (availability of information)

WHAT TO IMPROVE

The RKB does not claim to offer final solutions but to provide tools for exploring potential ones.

It provides valuable insights that allow mutual learning among stakeholders. However, as a solution intended to deliver data, models, and tools, it is not enough for stakeholders to enhance resilience in the region. Commercial software or company-owned platforms and tools limit their flexible incorporation in the digital RKB as it requires authentication screens to access data. The main benefits of the individual solutions, such as advanced visualization, already exist inside the company-owned tools. The main value of the RKB therefore lies in connecting stakeholders and raising their awareness of these technologies.



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RKB - Transformational potential

A LONG TERM VISION CO-DEVELOPED WITH STAKEHOLDERS

The RKB platform is a tool addressing climate risks with a long-term vision. It can boost a participatory approach to adaptation due to the extensive interactions with stakeholders organised for co-create the RKB. The spatial scale is the entire region of Zeeland - Rijnmond and can be further extended to cover other Dutch regions facing similar issues. Considerable attention was given to the equity of the measures, by sharing solutions and pathways that aim to make elderly and vulnerable people less exposed to the risk of heat stress. Conversely, no major changes are expected in the fundamental attributes of the socio-ecological system, but more actionable information and better-informed decisions.

TRANSFORMATION ELEMENT	SCORE
TEMPORALITY: Long-term vision/expected to produce long-term and durable outcomes	5
INCLUSIVITY: Co-developed/discussed with stakeholders	5
SCOPE: Developed at scale or easily scalable	4
INCLUSIVITY: Consideration for the equity of measures, attention for vulnerable groups	4
SCOPE: Responsive (flexible) to changing conditions	4
SCOPE: The RKB platform includes a multi-sector approach	2
DEPTH OF CHANGE: Novel approach for the region	2
DEPTH OF CHANGE: Expected to generate radical shift or large restructuring in your region	1

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ADAPTATION PATHWAYS TO ADDRESS HEAT STRESS

Content

INTRODUCTION

Adaptation pathways are sequences of adaptation measures that are planned to be progressively implemented to cope with the increasing or evolving risks posed by climate change. The implementation of additional, different or larger measures is triggered when current adaptation measures and policies are no longer effective to withstand climate change (tipping points), marking the need to shift to different and more effective solutions. The IMPETUS methodology for developing adaptation pathways (AP methodology) was applied in the seven project demo-sites.

Stakeholder interactions were performed in each region with formal events and informal interactions. Interactions were continuously ensured from the beginning and across all the process of pathway development, also considering that key stakeholders include public administrations and utilities. Stakeholders were specifically consulted for discussing adaptation options and adaptation pathways, and their feedback was used to refine or even change the final outcomes. Historically focused on flood risks, the region now faces increasing temperatures and humidity, as expected under future climate scenarios, leading to severe health issues, higher energy consumption, and worsening living conditions.

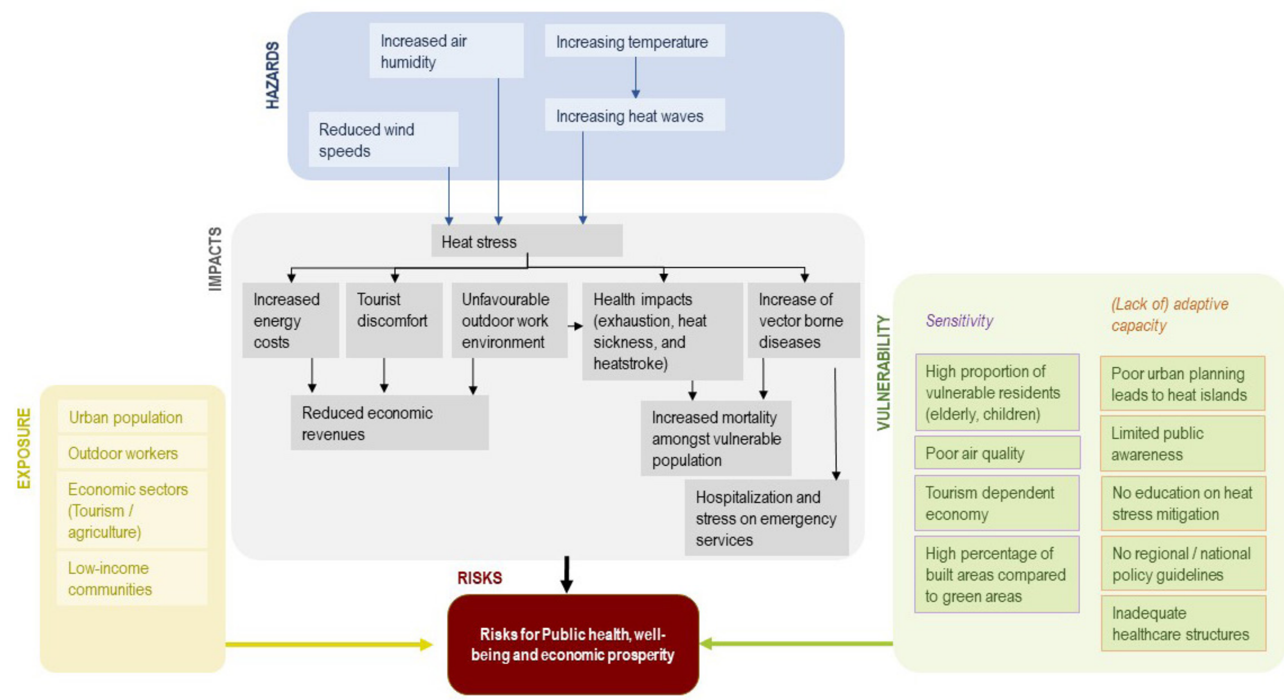
The **main objective** of the Adaptation Pathways for the Zeeland region was to propose alternative routes for **reducing the impacts of heat stress on human health** based on current and future risks posed by climate change. The key measurable indicator selected for the pathways is the Physiological Equivalent Temperature (Koopmans, S., Heusinkveld, B. G., & Steeneveld, G. J., 2020), used to determine maximum tolerable increases in temperature for a specific location.

THE IMPACT CHAIN

Impact chains (GIZ and EURAC, 2017; Zebisch et al., 2022, 2023) are useful tools to delineate conceptual models for climate change risk assessment. They are cause-effect chains that include all major factors and processes leading to specific climate risks in a specific context.

Heat stress in the Zeeland region is projected to increase under future climate change scenarios. These climate risks pose a significant risk to human health, economic stability and environmental sustainability. In the Netherlands, heat stress is particularly relevant in the province of Zeeland, where the novel topic of heat stress due to rising temperatures is combined with several vulnerability elements, intensifying the impacts. In Zeeland, heat stress is driven by rising local temperatures, increased humidity, and reduced wind speeds. Climate change intensifies these conditions, leading to more frequent heatwaves and higher physiological stress for the population. The impacts are both health-related and economic. Health effects include direct consequences like heat exhaustion, strokes, and increased mortality among vulnerable groups, alongside indirect pressures such as overburdened healthcare systems, medication storage issues, and more frequent emergencies and minor accidents.

Heat stress also facilitates the spread of pathogens. Local factors such as the urban heat island effect and poor air quality worsen the situation, particularly for sensitive populations like the elderly. Economically, heat stress raises energy demand, lowers worker productivity, and diminishes the region's appeal for tourism. Zeeland's vulnerability is compounded by an ageing population (over 26% of residents aged 65 or older), and limited adaptive capacity. This refers to poor urban planning in historical centres (current urban planning strategies do not incorporate heat measures into urban design), limited health service capacity (with many medical facilities located far apart) and low public awareness. The lack of education and preparedness further weakens the community's ability to respond. Addressing these challenges requires enhanced urban planning, public education, and strategies to build local resilience.



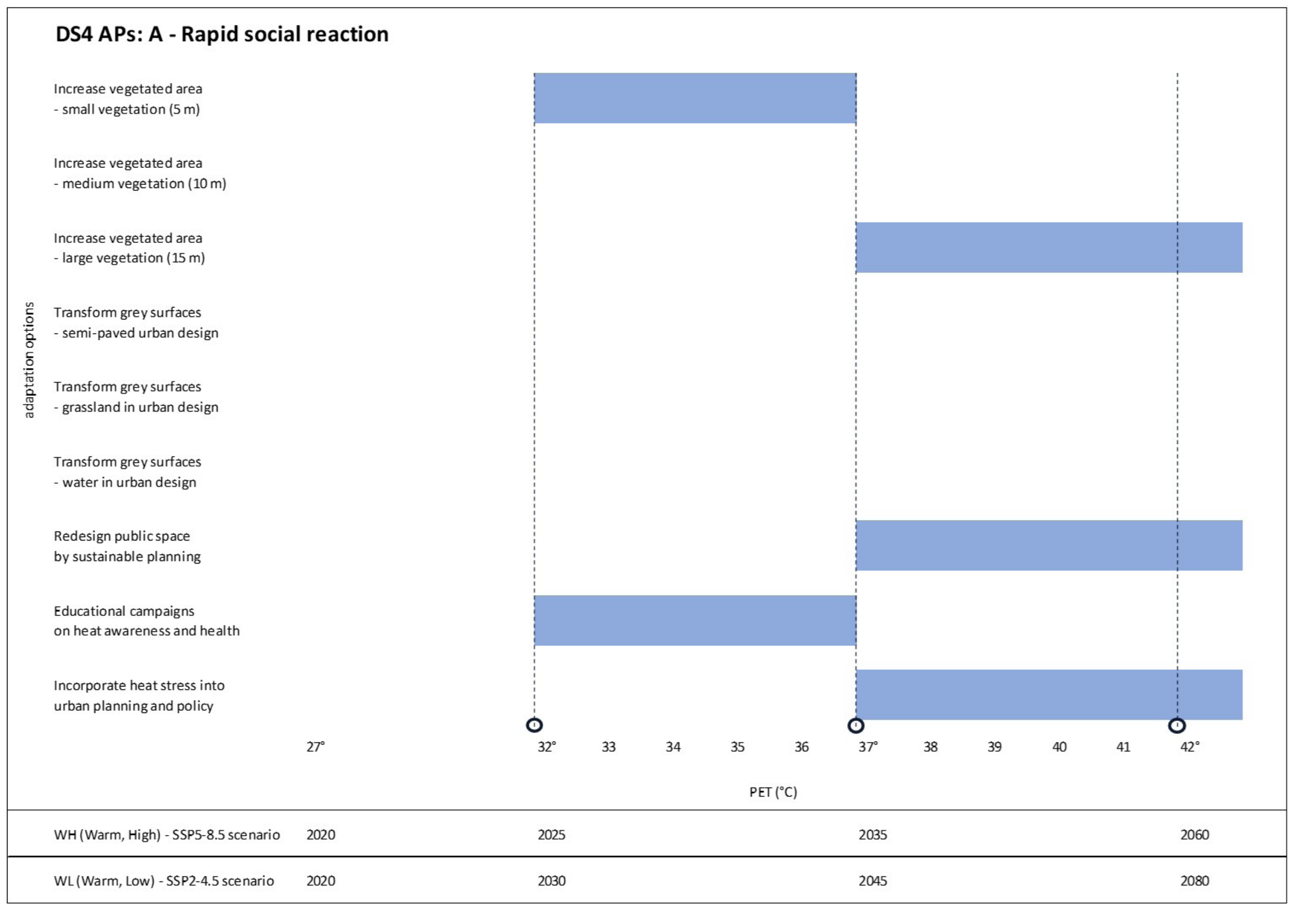
THE PATHWAYS MAPS

Stakeholder interaction resulted in the elaboration of three main adaptation pathways. They are based on three tipping points corresponding to three different intensity levels of heat stress, ranging from a comfortable baseline (up to 27°C PET, as the maximum daily experienced temperature), to severe or very severe conditions, hard to tolerate (up to 37°C and 42°C PET):

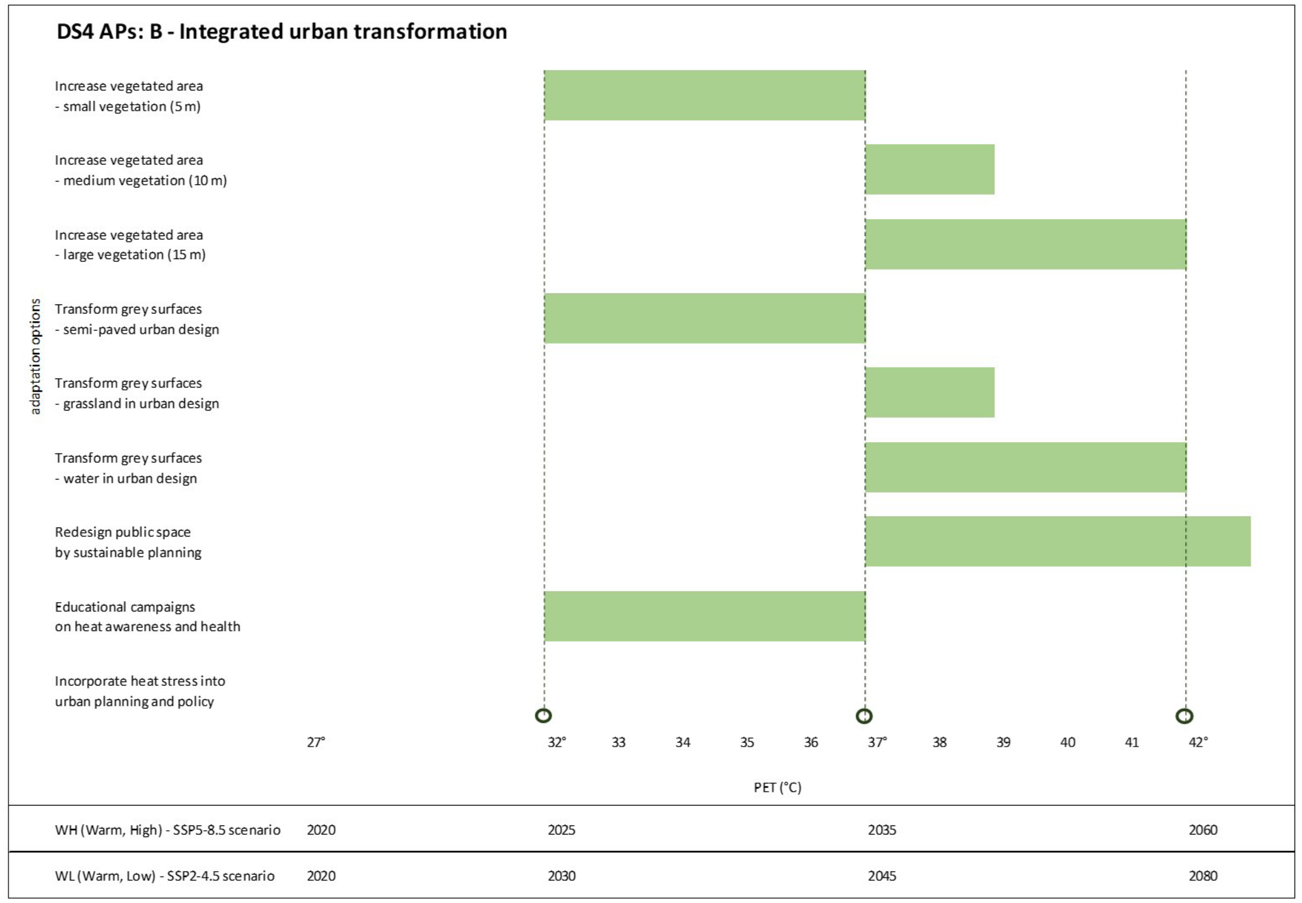
A. **Rapid social reaction**: this pathway is designed for swift action, addressing heat stress challenges rapidly and flexibly. At the first tipping point, the focus is on deploying fast, low-cost measures. This includes urgent public awareness initiatives and temporary, small urban greening interventions. Medium-term actions, upon reaching tipping point two, involve the rapid implementation and scaling up of larger measures such as sustainable urban planning. and enhancing urban greening through larger vegetation. Based on real-time community feedback, this approach can be refined and accelerated or slowed. After the third tipping point, adaptive structural interventions are continued and expanded to ensure that cities remain agile and responsive to evolving climate conditions, while strategies are continuously monitored and adjusted for maximum effectiveness.

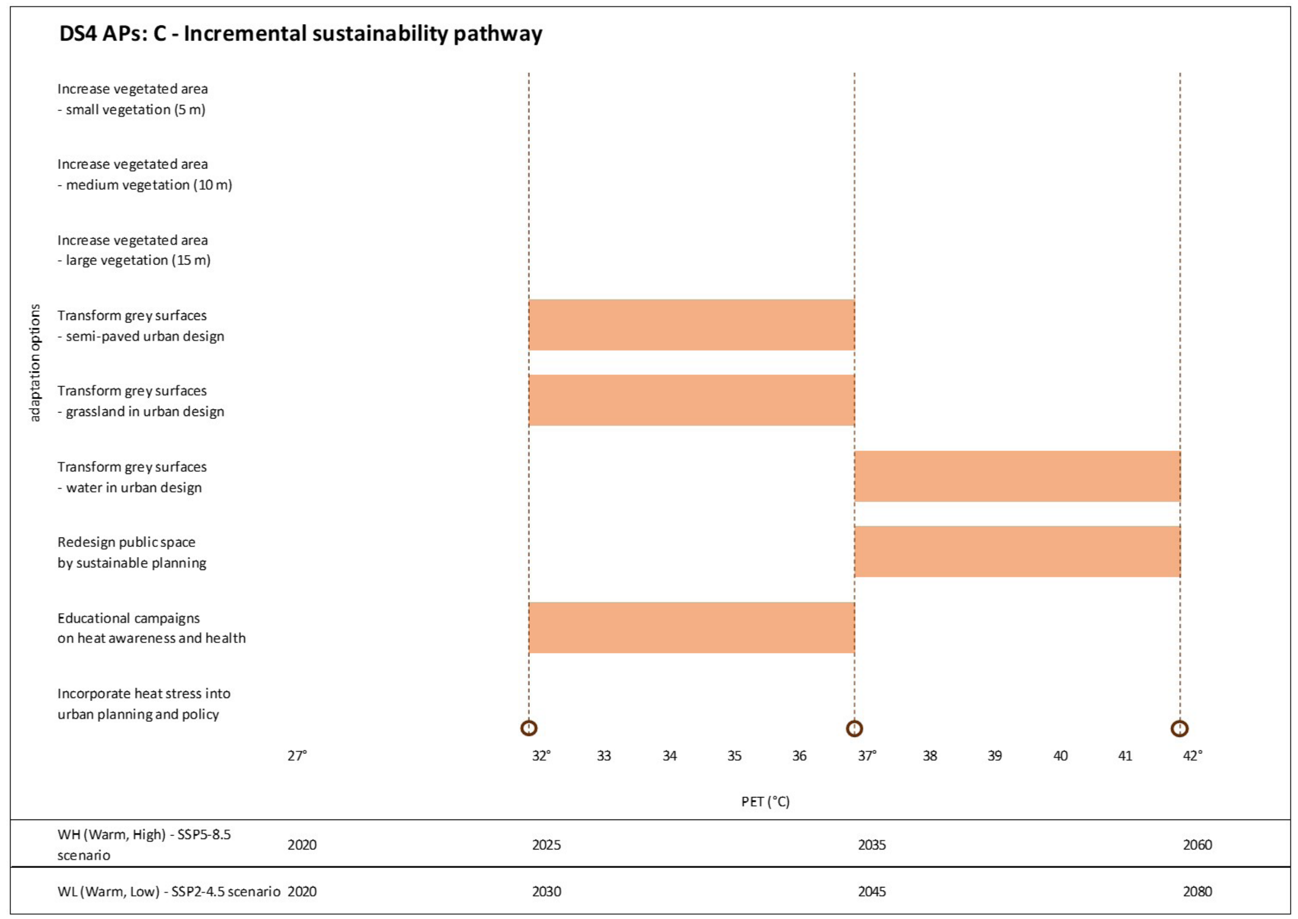
B. **Integrated urban transformation**: Integrated urban transformation envisions a comprehensive and complete change of the urban environment, embedding heat stress adaptation into every facet of urban planning. In the short term (tipping point one), initial non-structural measures are paired with low-investment interventions supporting the transformation of urban design. As tipping point two is approached, a broader redesign of the urban environment takes place, integrating green and blue infrastructure and both medium- and large-scale vegetation. By the third tipping point, the transformation is implemented city-wide, establishing a resilient, future-proof urban landscape that not only mitigates heat stress but also enhances overall liveability.

C. **Incremental sustainability**: Within this final pathway, a more pragmatic, step-by-step approach is adopted, tailored to the city's current resources. At tipping point one, the focus is on low-cost, rapidly implementable non-structural measures such as targeted heat awareness campaigns. This is strengthened by incrementally removing grey surfaces in the city through small-scale urban greening. By tipping point two, these initiatives gradually expand with moderate structural interventions that reinforce local resilience, such as more advanced urban greening. After the third tipping point, larger measures continue where proven effective, ensuring that investments remain sustainable and aligned with local budget constraints.



figures: DS4 Adaptation Pathways Maps





Adaptation pathways - Exploitation potential

STAKEHOLDERS INTEREST

score 4/5

MAIN STAKEHOLDERS INVOLVED: STATE GOVERNMENT AND POLICY

The main involved stakeholders were the municipalities together with local and regional representatives. In earlier stages, the approach was also discussed with academia. While their interest was high, the focus remained on scientific details rather than practical application.

FEEDBACK FROM STAKEHOLDERS

Stakeholders appreciated the approach for its clarity and practical relevance. The pathways offered a useful way to explore different measures against heat stress.

Although there were differing views on specific details (such as the exact quantification of adaptation measures), the general concept was well received. In the end, to improve the usability, it would be needed to have more information on the cost-benefits than could be provided at this time. It was also something municipalities were already somewhat familiar with, due to the DAPP method developed by Deltares in the Netherlands. However, it had not yet been translated into practical solutions for their specific challenges.

In the end, to improve the success, it would be needed to have more information on the cost-benefits than could be provided at this time.

OPPORTUNITIES TO USE ADAPTATION PATHWAYS

score 3/5

The adaptation pathways have potential to **effectively explore the impacts of different strategies**. They can provide clear and easy-to-understand insights into the cost-benefit analysis of the various choices policymakers must make, thereby helping to simplify the decision-making process. This would entail making effective strategies for heat stress policies, or adaptive building guidelines. However, in practice, a lot of practical data and information is needed to make real-time decisions. Often, stakeholders must adhere to many guidelines and considerations which might not only be financial and environmental, but also can be political, or choices between social investments. This makes climate adaptation sometimes more of a synergy opportunity rather than a direct course of action.

As a result, opportunities for using the adaptation pathways are present, but not always prominent.

Adaptation pathways - Gaps & needs

CHALLENGES - HOW TO TRANSLATE PATHWAYS INTO PRACTICE

Knowledge challenges come first: the details and approach used rely heavily on underlying information (such as the costs, benefits, and net effects of measures). Since this data was limited, often highly technical, and typically known only by academics or experts in the field, **the needed information is not readily available**. This limits trust in the outcomes which is needed to be turned into practice. Combined with existing governmental challenges, trust between governmental actors and citizens hinders the applicability of the approach. This relates back to reliable data and outcomes.

Additionally, local stakeholders face difficult trade-offs across several aspects, socio-political, financial, environmental, and between citizens. Currently, the topic is not pressing enough to be a high priority for action, resulting in **limited funding**. Moreover, it is difficult to make policies that require significant financial investment based on uncertain future and uncertain pathways. Another challenge is the risk of setbacks if the data proves inaccurate or is updated based on new insights. This requires highly dynamic revision to the pathways, and therefore **adaptive governance**.

PRIORITY	CHALLENGES
1	Knowledge challenges (availability of information)
2	Capacity challenges (ability, resources and motivation to use knowledge for action)
2	Financial challenges
3	Governance challenges

WHAT TO IMPROVE

To improve the approach's acceptance and usability, more detailed and accessible information on the cost-benefit aspects of adaptation measures is needed. At the current stage, the data available is insufficient to fully support informed decision-making, limiting stakeholders' confidence in applying the pathways in practice.

Adaptation pathways - Transformational potential

ELEMENTS OF TRANSFORMATION

By using the developed pathways, insights are generated into local adaptation measures against heat stress, a topic that disproportionately affects **vulnerable populations**, as they often lack the ability and means to address these hazards themselves. By using the developed AP, vulnerable populations are effectively included in the conversation, making climate policy more inclusive and incorporating the social aspect. The approach for developing the adaptation is **scalable**. It would require following the methodology again, with a focus on the new scale and local characteristics, which can be done easily. The methodology allows the adaptation pathway approach to be easily scaled from regional to local levels by repeating the process with a focus on the new scale and specific local characteristics. While the methodology envisions the use of a **multi-sector approach**, not all sectors were involved in its development. Municipalities are also dependent on higher-level authorities for decision-making on policies.

The adaptation pathways were developed with **part of the defined stakeholder group**, primarily local authorities (municipalities). Unfortunately, this did not include all the relevant stakeholders (academia, experts) within the DS, which would have benefited the overall development. The developed adaptation pathway at the DS level is **novel** to the region. No earlier case-specific pathway had been set up with this level of detail. However, the concept of Dynamic Adaptive Policy Pathways (by Deltares) was already known. If implemented, the methodology of the adaptation pathways has the potential to be **responsive** to changing climatic conditions. However, it requires iteration of the steps in the methodology. This might not be simple (due to data constrains, rapid changes) and requires extensive work, which makes it less flexible.

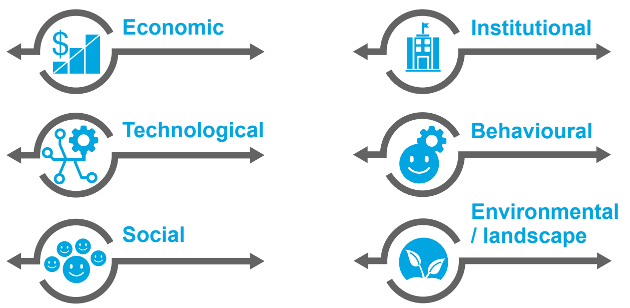
Currently, no long-term implementation of the adaptation pathways is expected in the DS. The stakeholders would need to be dedicated to the approach to make **long-term impacts**. It might be used on short-term, by ways of exploration, with short-term durable outcomes. If positive, it might be extended to produce long-term outcomes.

The adaptation pathway approach has strong potential to drive **major urban transformation** for heat stress adaptation. However, at the current stage, it is not expected to be applied to that extent. Local factors and uncertainties hinder its full application, and more research and discussions are needed before it can be implemented on this scale.

TRANSFORMATION ELEMENT	SCORE
INCLUSIVITY: Consideration for the equity of measures, attention for vulnerable groups	4
SCOPE: Developed at scale or easily scalable	4
SCOPE: The AP elaboration process includes a multi-sector approach	3
INCLUSIVITY: Co-developed/discussed with stakeholders	3
DEPTH OF CHANGE: Novel approach for the region	3
SCOPE: Responsive (flexible) to changing conditions	2
TEMPORALITY: long-term vision/expected to produce long-term and durable outcomes	1
DEPTH OF CHANGE: Expected to generate radical shift or large restructuring in your region	1

IMPACT OF TRANSFORMATION

Applying the adaptation pathways to the local climate risk of heat stress would foster positive system change in all below mentioned sectors. It could make a positive change in all different societal layers depending on the chosen pathways. The pathways allow for choices between the options, but requires definitely, environmental/landscape transformation, societal and economic transformation, and might induce social and behavioural chances. By this all, a technical transformation would be inevitable.



A PORTFOLIO OF CLIMATE ADAPTATION SOLUTIONS

Content

Fifteen adaptation solutions to address flood and heat stress due to temperature increase were assessed. Two of them were specifically tested in IMPETUS: Heat Awareness System and the Decision support system for Flood Risk Management. In order to facilitate comparison among the high variety of adaptation options considered across all DSs, adaptation options were categorised according to the Key-Type-of-Measure (KTM) system, defined at the European level (Leitner et al., 2021) as voluntary mechanism to report climate adaptation actions in the EEA member countries, as part of the EU Regulation on Governance of the Energy Union and Climate Action Energy Union Governance Regulation (2018/1999). The two solutions tested in IMPETUS belong to the category E1 that include decision support systems and databases. A large share of the other solutions embraces Green options (D1), aiming to make the Zeeland urban environment a greener space, with expanded vegetated areas, permeable surfaces, green roofs and other green elements in private properties. Green solutions are complemented by artificial shading structures to provide cooler public space and energy-efficient cooling systems (Grey options, C1). All these structural solutions are supported by Inclusive sustainable planning that also incorporates heat stress in spatial planning and Community cooling programmes for vulnerable groups (A2 – management and planning). Actions to boost behavioural changes are finally considered (E2 capacity building, empowering and lifestyle actions).

OPTION	DESCRIPTION	MAIN OBJECTIVE(S)	IMPETUS CLIMATE RISK	KEY TYPE OF MEASURE	TESTED IN IMPETUS
Decision support system for heat awareness	Interactive coupling of Heat Stress mapping with a 2D viewer (Digital Twin).	To improve the heat awareness systems and inform decision making.	Temperature increase	E1 – Information and awareness raising	Y
Decision support system for Flood risk	Integrated decision support tool coupling a flood risk model and a digital twin	To assess flood scenarios and enable decision makers to assess the implications of adaptation measures.	Temperature increase	E1 - Information and awareness raising	Y
Green roofs and walls	Roofs and walls covered with vegetation	To improve the insulation of buildings, decrease the heat island effect, and reduce the need for air conditioning.	Temperature increase	D1 - Green Options	
Expanding vegetated areas	Planting grassland, trees or other types of vegetation.	To enhance shade and cooling surfaces through evapotranspiration, help reduce air and surface temperatures.	Flooding risk	D1 - Green Options	
Improving urban shading	Increase shading through structures, such as shade screens.	To reduce direct exposure to sunlight, lower air and surface temperatures, provide cooler public spaces.	Temperature increase	C1 - Grey options	
Reducing grey surfaces	Incorporating semi-paved features in urban design; Incorporating grassland features in urban design; I ncorporating water features in urban design.	To reduce heat absorption and surface temperatures.	Temperature increase	D1 - Green Options	
Inclusive sustainable planning	Adopting a sustainable urban planning that include green spaces, water features, and shading.	To integrate sustainability in urban planning to make cities more resilient to rising temperatures.	Temperature increase	A2 - Management and planning	
Green infrastructure in private properties	Install green roofs, walls, and other vegetation on private property.	To cool buildings and reduce heat island effect.	Temperature increase	D1 - Green Options	
Technical cooling innovations	Energy-efficient cooling systems, reflective materials, and smart cooling solutions.	To reduce indoor and outdoor temperatures.	Temperature increase	C1 - Grey options	
Adaptive behaviours and practices	Encouraging people to adopt heat-reducing practices.	To support reducing personal exposure to heat.	Temperature increase	E2 - Capacity building, empowering and lifestyle actions	
Early warning systems (EWS)	EWS alert vulnerable populations to impending heatwaves, allowing them to take preventive actions	To alert the vulnerable population of impending heatwaves.	Temperature increase	C2 - Technological options	
Switch to energy efficient appliances	Energy-efficient appliances reduce the heat generated indoors while lowering energy use	To improve indoor thermal comfort.	Temperature increase	C1 - Grey options	
Community cooling programmes for vulnerable groups	Establishment of programmes that provide access to cool spaces for vulnerable population	To reduce the risk of heat-related illnesses and promote awareness programmes.	Temperature increase	A2 - Management and planning	
Educational campaign on heat awareness and health	Campaigns should raise awareness of heat risks and promote behaviors to decrease heat stress	To raise awareness of heat risks and promote behaviours to help individuals reduce heat stress.	Temperature increase	E2 - Capacity building, empowering and lifestyle actions	
Incorporation of heat stress considerations into urban planning and policy	Prioritize shading, greenery, and cooling strategies in urban planning.	To ensure that future infrastructure and developments prioritize shading, greenery, and cooling strategies to combat rising urban temperatures.	Temperature increase	A2 - Management and planning	

Portfolio of solutions - Evaluation

All solutions are quite mature since they are characterized by medium to high technological and social readiness level (TRL and SRL). The solutions considered most effective are "Sustainable urban planning" and "Incorporation of heat stress considerations into urban planning and policy", being potentially able to reduce local conditions of heat stress by 25%. The implementation of these two solutions will bring increased city preparedness to heatwaves, reduced health impacts and increased social cohesion. The green measures, both envisaged in public spaces and in private properties, are also expected to enhance biodiversity and environmental quality. Moreover, almost all measures assessed in this demo-site have a potential for creating synergy with mitigation, due to improved energy efficiency (switch to energy efficient appliances), reduced energy consumption (green infrastructure and green roofs in private properties), carbon sequestration (green infrastructure both in public and private areas) and increased awareness about climate change.

While the assessed measures were considered relevant to support vulnerable groups in addressing heat stress, inequality side-effects may occur, if measures are not properly implemented. This refers for example to a possible unfair access to information, potential risk of exclusion from cooling programs, gentrification of certain urban areas and costs to be sustained by private owners for initial investments and maintenance. Finally, if measures are extensively implemented and deeply transform the urban environment, conflicts among stakeholders about the use of space should be considered, public consultation should be organised and resistance to change, especially for the elderly, needs to be addressed.

		ASSESSMENT													GAPS & NEEDS for implementation
#	Synthetic name of the option	Effectiveness for the expected objective	Lifetime	Feasibility - TRL	Feasibility - SRL	Economic costs	Benefits	Evaluate Environmental benefits	Evaluate Social benefits	Negative unintended effects/hidden risks	Evaluate Environmental negative unintended effects/ hidden risks	Evaluate Social unintended effects/hidden risks	Implementation time	Synergy with mitigation	
1	Decision support system for heat awareness						Enable decision makers to assess the impolications of adaptation measures. Support decision makers to make informed decisions with respect to spatial planning.							No	Technical challenges need to be overcome: definition of area size, integration of data from different models. Limited number of measure can be simulated.
2	Decision support system for Flood risk						Develop flood scenarios, including the visualization of changing water levels over space and time.							No	Technical challenges need to be overcome: definition of area size, integration of data from different models. Limited number of measure can be simulated. Data needs: Digital elevation model (DEM), Lan use map, Friction map, Infiltration map, Hydraulic structures, Levee system, Sewerage system, Improved elevation data, API system for the integration of Digital twin + 3 Di, Potential plans for spatial developments.
3	Green roofs and walls	++	++	+++	++	- -	Rainfall storage. Biodiversity. Aesthetic view.	+++		Damage by vegetation. Water infiltration because of faulty waterproofing. Maintenance.	-		- -	Yes	
4	Expanding vegetated areas	++	+++	+++	+++	- -	Improved social cohesion. Environmental quality. Access to areas.	+++	+++	Potential conflicts between stakeholders over space use. Insufficient public consultation mechanisms.		-	- -	Yes	
5	Improving urban shading	++	+	+++	+++	- -	Improved human wellbeing. Recreational opportunities. Biodiversity enhancement.	+	+	Habitat disruption. Gentrification. Maintenance costs.	-	-	-	Yes	
6	Reducing grey surfaces	++	++	++	++	- -	Improved social cohesion. Environmental quality. Access to areas.	++	++	Potential conflicts between stakeholders over space use. Insufficient public consultation mechanisms.		-	-	Yes	
7	Inclusive sustainable planning	+++	+++	++	+++	- - -	Improved social cohesion. Environmental quality. Access to areas.	+++	+++	Potential conflicts between stakeholders over space use. Insufficient public consultation mechanisms.		- -	- - -	Yes	
8	Green infrastructure in private properties	++	++	++	+	- -	Enhance biodiversity. Reduced energy costs.	+	+	Maintenance and costs for private owners.		-	-	Yes	
9	Technical cooling innovations	+	+	+++	++	- -	Reduced energy usage and GHG emissions.	+	+	High initial investment costs.		-	-	Yes	
10	Adaptive behaviours and practices	++	+	+++	++	-	Reduced vulnerability and rapid incentive.		+	Resistance to change amongst elderly (vulnerable).		-	-	Yes	
11	Early warning systems (EWS)	++	++	+++	++	- -	Increased public resilience. Development of technologies.		+	Inequality in access of information based on technical personal skills.		-	-	Yes	
12	Switch to energy efficient appliances	+	+	+++	+++	- -	Lower energy bills. Reduce emissions.	++	++	High upfront costs. Limited access by vulnerable groups.		-	-	Yes	
13	Community cooling programmes for vulnerable groups	++	+	+++	+++	-	Involvement in wider climate problems.		++	Potential risks of exclusion.		-	-	Yes	
14	Educational campaign on heat awareness and health	+	+	+++	++	-	Increased resilience of a wider population of newer generations.		+	Language barriers. Inequality in information access. Trust in governmental actors.		-	-	Yes	
15	Incorporation of heat stress considerations into urban planning and policy	+++	+++	++	++	- -	Improved preparedness. Reduced health impacts. Tourism increase.		++	None.	-	-	- - -	Yes	

Portfolio of solutions - Transformational potential

ELEMENTS OF TRANSFORMATION

The set of measures outlines a good potential for transformation as the average scoring of all solutions is 3.4 (on a scale of 5). In particular, measures are deemed highly responsive to climate change, but also scalable and future-looking, with durable and long-term outcomes. On the other side, the assessed solutions are not expected to generate a radical shift or large restructuring of the regional characteristics, but rather to incrementally introduce small elements of change. While certain measures include specific attention to vulnerable groups, and measures have been quite extensively discussed with stakeholders, equity and fair adaptation remains an attribute to further consider and expand. The strongest overall potential (considering all attributes) resides in the Decision Support Systems and in the urban planning solutions, in particular for their capacity to be responsive to changing climatic conditions and to include a multisector approach. The lowest transformational potential resides in some small but important technological innovation (for cooling or for reducing energy).

	SCOPE			DEPTH OF CHANGE		INCLUSIVITY		TEMPORALITY
Synthetic name of the option	Include a multi-sector approach	Responsive to changing climatic conditions	Developed at scale or easily scalable	Novel for the region	Expected to generate radical shift or large restructuring in your region?	Co-developed/ discussed with stakeholders	Consideration for the equity of the measure with specific attention to vulnerable groups, marginalised communities and gender balance	Expected to produce long-term and durable outcomes
Decision support system for heat awareness	4	4	5	5	4	5	4	5
Decision support system for Flood risk	4	4	4	4	3	5	2	4
Green roofs and walls	4	4	3	3	3	3	2	4
Expanding vegetated areas	4	5	4	2	3	3	3	4
Improving urban shading	3	4	4	3	3	3	2	3
Reducing grey surfaces	3	4	3	2	2	3	2	3
Inclusive sustainable planning	5	5	4	4	4	3	5	4
Green infrastructure in private properties	3	4	3	3	3	3	2	2
Technical cooling innovations	2	4	3	4	2	3	2	3
Adaptive behaviours and practices	3	4	4	3	2	3	4	4
Early warning systems (EWS)	4	4	4	4	2	3	3	3
Switch to energy efficient appliances	2	4	3	4	2	3	2	3
Community cooling programmes for vulnerable groups	3	4	4	3	2	3	4	4
Educational campaign on heat awareness and health	3	4	4	3	2	3	4	4
Incorporation of heat stress considerations into urban planning and policy	5	5	4	4	4	3	5	4

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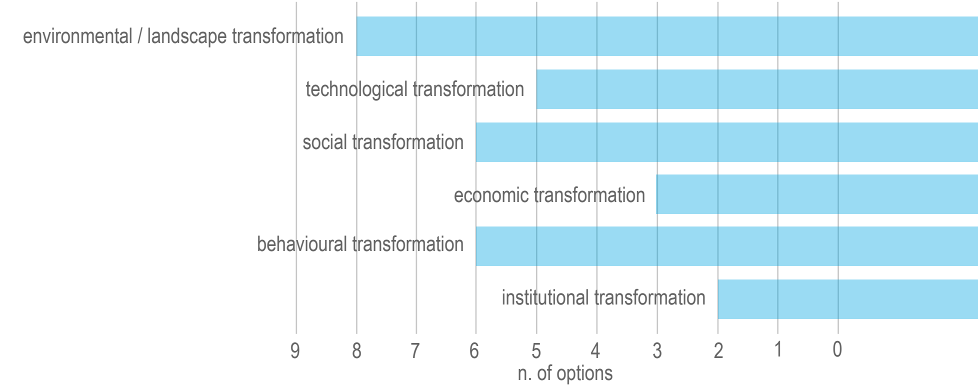
Portfolio of solutions - Transformational potential

IMPACT OF TRANSFORMATION

The majority of solutions, if implemented in the Zeeland region, would entail large changes in the environment and the landscape, due to new green areas, also supported by decision support tools and more sustainable and heat-oriented spatial planning of the urban areas. Environmental transformation is followed by social and behavioural transformation generated by educational campaigns and adaptive behaviours. Social transformation is also expected from people fruition of public green spaces, while behavioural transformation is generated by green elements in private properties that require new awareness on their heat stress mitigation potential. A technological transformation is expected from the use of decision support tools and early warning systems, as well as from some technological innovations for cooling and energy-efficient appliances that also contribute to generate changes in the economic system. Finally the management and planning options for climate proofing urban spatial planning could generate changes in how institutions are arranged and make decisions.

Figure: Impacted sectors



IMPACT OF TRANSFORMATION						
Synthetic name of the option	Economic transformation	Technological Transformation	Social transformation	Institutional transformation	Behavioural transformation	Environmental / Landscape transformation
Decision support system for heat awareness		X				X
Decision support system for Flood risk		X				X
Green roofs and walls					X	X
Expanding vegetated areas			X			X
Improving urban shading			X			X
Reducing grey surfaces			X			X
Inclusive sustainable planning				X		X
Green infrastructure in private properties	X				X	
Technical cooling innovations	X	X				
Adaptive behaviours and practices			X		X	
Early warning systems (EWS)		X			X	
Switch to energy efficient appliances	X	X				
Community cooling programmes for vulnerable groups			X		X	
Educational campaign on heat awareness and health			X		X	
Incorporation of heat stress considerations into urban planning and policy				X		X

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