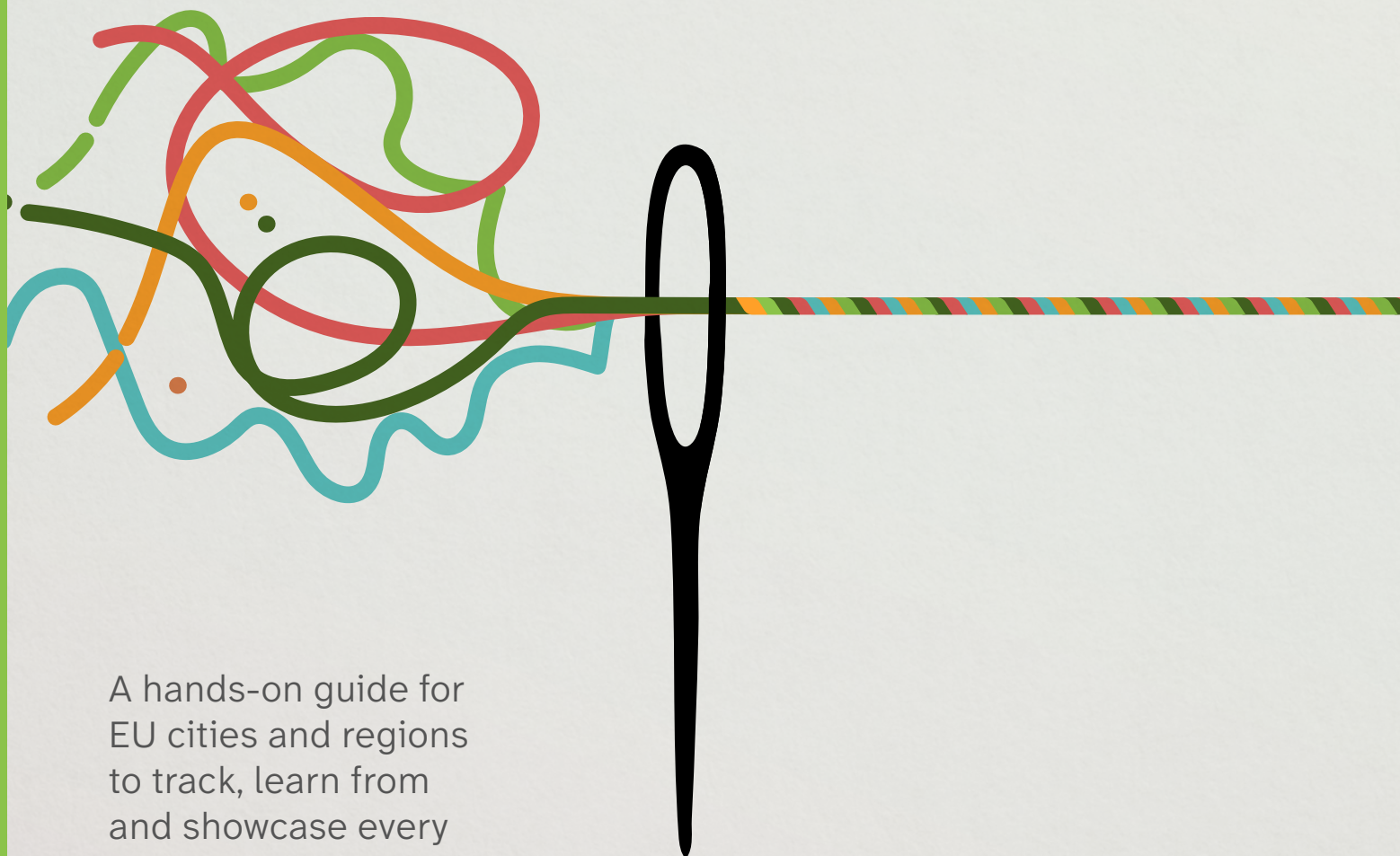


From Plans to Practice:

Smart Monitoring for Regional Climate Adaptation



A hands-on guide for
EU cities and regions
to track, learn from
and showcase every
adaptation move

OCTOBER 2025

Colophon

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Table of Contents

Monitoring and Evaluation: What is it and why does it matter?	6
The What	6
The Why	6
Challenges	7
Monitoring adaptation measures – a step-by-step approach	8
Laying the Groundwork – Considerations before you begin	
Steps for building an integrated monitoring framework	10
Step 1: Define Purpose and Scope	
Step 2: Develop (or refine) an impact model (Theory of Change or Results Chain)	
Step 3: Identify indicators	
Step 4: Set Baseline and Targets	
Step 5: Set up Data Collection and Management	
Step 6: Analyse, Prepare Results, and Communicate	
Monitoring in Practice: Key type measures	22
Examples from regions and of other existing indicator frameworks	28
Examples on how monitoring is already covered in regional adaptation plans	28
Climate Impact and Climate Adaptation Monitoring North Rhine-Westphalia, Germany	
Global Indicator of Climate Change Adaptation in Catalonia, Spain	
Other examples	
Resilience monitoring frameworks for inspiration	32
Conclusion	34
Literature	35



Executive Summary

This guidance document equips city and regional representatives with practical steps and proven approaches for effective monitoring of climate adaptation measures. Monitoring is vital for tracking progress, ensuring accountability, and learning from adaptation actions. It involves the continuous assessment of activities, while evaluation provides periodic, systematic reviews of their effectiveness and long-term impact.

Given the complex and evolving nature of climate adaptation, this document addresses key challenges and a step-by-step approach is presented, beginning with defining clear objectives, developing an impact model (such as a Theory of Change), selecting appropriate indicators, setting baselines and targets, and establishing robust data collection and management systems. It emphasises the importance of using both quantitative and qualitative indicators, engaging stakeholders, and ensuring transparent communication of results to inform policy and practice. The document also introduces the concept of key type measures – such as governance, economic, physical, nature-based, and knowledge measures – which help regions capture the full range of adaptation actions and their spillover effects.

Practical examples from European regions, such as North Rhine-Westphalia (Germany) and Catalonia (Spain), illustrate how comprehensive monitoring frameworks and tailored indicator sets are being implemented. The document also reviews established resilience monitoring frameworks, including the IMPETUS Resilience Metrics, the EU Sustainable Development Goals, and the ISO 37123 standard, highlighting their strengths and limitations for regional adaptation monitoring.

These examples and frameworks provide valuable inspiration for developing robust, context-specific monitoring systems that support effective climate adaptation and resilience building.



OBJECTIVES



MONITORING



EVALUATION



Picture: Monitoring North Rhine-Westphalia (Germany) practical example. Climate Impact and Adaptation Monitoring in NRW on the screen.

Gender statement

The need for gender mainstreaming arises from persistent inequalities in power distribution and access to services and opportunities between people of different sex and/or gender identities. As demonstrated by literature and advocated at the European and international arena, this influences the understanding and perception of climate change dynamics and effects. Women and men, but also people in the LGBTQI+ community, are differently affected by the accelerated change of climate. Only by taking into consideration their diverse visions can scientific research reach meaningful and universal conclusions that properly inform climate action.

For these reasons, the REGILIENCE consortium is committed to including gender and intersectionality as a transversal aspect in the project's activities. In line with EU guidelines and objectives, all partners – including the authors of this deliverable – recognise the importance of advancing gender analysis and sex-disaggregated data collection in the development of scientific research.

Therefore, they commit to paying particular attention to including, monitoring and periodically evaluating the participation of different genders in all activities developed within the project, including workshops, webinars and events but also surveys, interviews and research, in general.

While applying a non-binary approach to data collection and promoting the participation of all genders in the activities, the partners will periodically reflect and inform about the limitations of their approach.

Through an iterative learning process, they commit to plan and implement strategies that maximise the inclusion of more intersectional perspectives in their activities. Within this deliverable, gender aspects were also considered by aiming towards being gender-neutral in all activities, such as workshops, interviews and surveys.



Picture: Telraam traffic counting

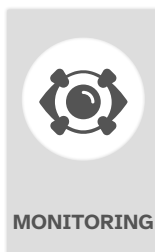
Monitoring and Evaluation: What is it and why does it matter?



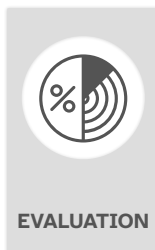
Picture: European Urban Resilience Forum. ©REGILIENCE

The What

Monitoring and Evaluation (M&E) are two closely linked, yet different processes:



Monitoring refers to the continuous assessment of progress in implementing activities, tracking whether actions are being carried out as planned and if interim targets are being met.



Evaluation is a periodic, systematic assessment of the relevance, effectiveness, efficiency, and impacts of adaptation measures, typically conducted at key milestones or upon completion of a project.

Evaluation seeks to assess the data captured during monitoring to check ongoing adaptation efforts and adjust them if necessary.

The Why

In this guidance document, we however focus mainly on monitoring. By establishing a strong monitoring framework, we lay the foundation for future evaluations, ensuring that reliable information is available when broader impact assessments are needed

Effective monitoring is an essential component of successful climate adaptation initiatives. They enable stakeholders to systematically track progress towards set objectives, assess the achievement of interim goals and milestones, and ensure that intended target groups are reached.

Through regular monitoring, regions can identify whether changing external conditions, such as shifts in the political, social or environmental landscape, are impacting the implementation of measures. Monitoring also provides a structured approach to identifying success factors, overcoming challenges and capturing valuable lessons learned. By fostering transparency and facilitating a shared learning process among all parties involved, monitoring highlights achievements and supports the responsible and efficient use of resources. Ultimately, robust monitoring empowers regions to adapt flexibly, build on proven approaches and enhance collective resilience in the face of a changing climate.



Picture: ARSINOE LivingLab Workshop in Athens, Greece using VR experiment to tackle environmental challenges. ©ARSINOE

Challenges

Climate adaptation is complex – it touches on environmental science, social issues, engineering, economics, and planning. No single field has all the answers, so expertise from different areas is needed. There are certain challenges related to monitoring that are particularly relevant for climate adaptation measures. These stem from the uncertain, non-linear and long-term nature of climate change.

For instance, it can be difficult to assess the **attribution** of a single intervention to the general adaptation outcomes, as individual adaptation measures are often just components of a larger adaptation strategy. Also, there is often a lack of baseline for **comparison**, meaning that it is difficult to answer the question, 'What would have happened in the absence of this intervention?'. While mitigation efforts usually have clear finish lines, adaptation is a **continuous process** that keeps evolving, which makes tracking progress much more challenging.

Furthermore, the potential effects of adaptation measures may only become apparent **over longer time periods**, making it challenging to report on their effectiveness within short time frames. Therefore, defining short- and medium-term goals and outcomes is an important step within the monitoring concept (Dinshaw et al., 2014). Also, there is always the risk of **maladaptation** in adaptation measures – this can be identified through monitoring but can also be hidden by chosen indicators for monitoring.



Monitoring adaptation measures – a step-by-step approach

Laying the Groundwork – Considerations before you begin

Consider monitoring from the outset when setting up a measure. Consider what you want to achieve, including any interim objectives, and clarify who the target group is.

What do you want to achieve with this measure? What do you want to change? What will success look like? Answering these questions will not only help with planning the measure, but also with later monitoring progress and evaluating its impact. Here are some questions you should consider:

Questions to ask in general:

- » What short-, medium- and long-term effects are to be achieved?
- » How can the effects be quantified?
- » What is the time horizon for achieving the objectives?
- » How are running costs financed?
- » Could there also be negative side effects?

Picture: Dimitar Yanchev, Unsplash



Define clear objectives early



Ask critical planning questions



Build shared understanding

Regional-level monitoring:

- » What are the aims of all activities, measures and policies? Do they increase regional resilience?
- » What institutions should be involved (e.g., for contributing data, sectoral agencies etc.)?
- » How can it be ensured that monitoring captures the vulnerabilities of various groups?

Monitoring of individual adaptation measures:

- » What is the main aim of the measure? Why do you want to monitor?
- » Who is involved in setting up and implementing the measure?
- » Who is the main target group? Are there other groups that could be affected by this measure, that are not the main target group?

It is important to build a shared understanding of the answers to the questions above. In addition, bear in mind that different disciplines are working together, both on measure and regional level. It is thus vital to create a shared understanding of climate adaptation and resilience terms and concepts.

The [IPCC glossary](#) can help provide standard definitions everyone can use so that stakeholders from different sectors are set on use the same language and no confusions arise.

Steps for building an integrated monitoring framework

Step 1: Define Purpose and Scope

At the beginning of the monitoring process, it is helpful to outline the scope as this enables resources to be prioritised and avoids unnecessary data collection outside the intended focus.

Specifying the purpose and scope at the onset also strengthens transparency, facilitates communication among stakeholders, and sets realistic expectations for the monitoring process.

Monitoring can serve various **PURPOSES**, some of which are:

Assessing progress	Determining whether adaptation measures/ policies/ other activities are being implemented as planned and if they are effective.
Informing decision-making	Providing evidence to adjust strategies, policies, or resource allocation, enabling policymakers and stakeholders to make informed choices about future adaptation priorities, and the allocation of resources.
Accountability	Demonstrating results to funders, governments, or the public.
Learning and improvement	Identifying what works, what doesn't, and why, to improve future adaptation actions.
Reporting	Fulfilling reporting requirements at local, national, or international levels (e.g., for climate funds or the Paris Agreement).

Regional-level monitoring:

- » **Assessing progress** across sectors and administrative boundaries.
- » **Support regional planning:** Information for regional development strategies and investment priorities.
- » **Accountability:** Demonstrate results to diverse regional stakeholders (residents, businesses, regional authorities).
- » **Reporting:** Address regional resilience frameworks (e.g., regional climate adaptation plans).



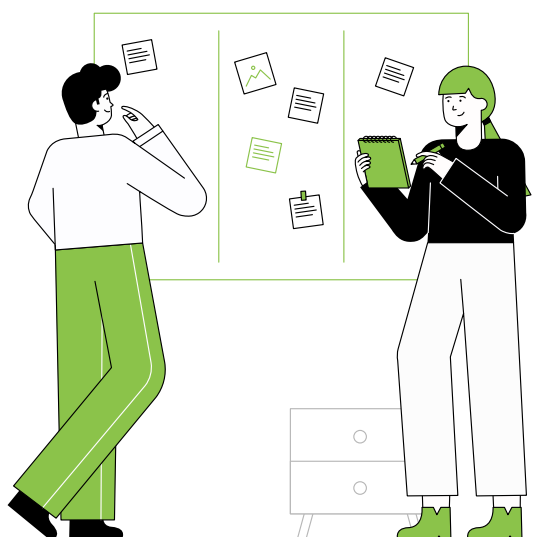
Establish clear purpose
and scope first



Identify key
monitoring functions



Address
regional-level needs



The **SCOPE** defines what will be monitored and evaluated, where, and over what period. It sets boundaries to keep the process focused and manageable. Aspects to consider:

Geographical area	Which region(s) or administrative areas as well as functional unit (e.g. watershed area) are included?
Timeframe	What period will be covered (e.g., past 5 years, ongoing)?
Thematic focus	Which adaptation sectors or themes (e.g., water, agriculture, health)?
Types of measures	Are you monitoring policies, projects, behavioural changes, or all adaptation actions?
Level of impact	Which level of impact are you looking at? Short-term results (outputs), medium-term effects (outcomes), long-term effects (impact) or all of the above?

Regional-level monitoring:

- » **Geographical area and types of interventions:** Consider all resilience-building activities across the region that are likely to have an impact on the thematic focus identified earlier, including systemic and institutional changes. Include non-labelled adaptation measures – many impactful actions are driven by economic, legal or service goals but still strengthen resilience.
- » **Thematic focus:** Regional adaptation pathways should reflect local climate hazards and socio-economic profiles. Consider all multiple interconnected sectors relevant for the specific climate hazard and their systemic interactions rather than individual sectors.
- » **Types of interventions:** All resilience-building activities across the region, including systemic and institutional changes. Consider all resilience-building activities across the region that are likely to have an impact on the thematic focus identified earlier, including systemic and institutional changes. Include non-labelled adaptation measures – many impactful actions are driven by economic, legal or service goals but still strengthen resilience.
- » **System-level impacts:** Long-term resilience outcomes and regional vulnerability reduction.
- » **Level of impact:** The level of impact is more focused on longer term results, thus rather monitoring at an outcome or impact level.
- » **Governance levels:** Multiple administrative levels and cross-border coordination.



Define
monitoring boundaries



Take a comprehensive
regional approach



Focus on
system-level outcomes

Step 2: Develop (or refine) an impact model (Theory of Change or Results Chain)

To understand the results and effects of adaptation endeavours and to plan monitoring effectively, it is useful to develop an impact model.

An impact model (sometimes called a results chain or theory of change) shows how adaptation measures are expected to bring about positive changes.

It clarifies which steps and intermediate goals are involved and how they are connected. Without an impact model, monitoring efforts often become unfocused, measuring activities without understanding whether they contribute to meaningful change. The model serves as your roadmap, helping you identify what to monitor at each stage and ensuring your indicators actually measure progress toward your goals rather than just tracking busy work (GIZ et al. 2020).

Once in place, the planned activities – such as constructing new infrastructure, providing training, or launching awareness campaigns – are carried out, with the quality and efficiency of **implementation** playing a crucial role in achieving the intended results. The immediate, tangible, short-term **outputs** of these activities, such as the number of workshops delivered, hectares of land restored, or new policies adopted, provide clear evidence that progress is being made. In the medium term, these outputs lead to meaningful **outcomes** for the direct target group, which may include improved knowledge, increased resilience, or positive behavioural changes.

Ultimately, the long-term impact of these adaptation efforts is seen in enhanced climate resilience, reduced vulnerability, and improved ecosystem health, reflecting the broader and lasting success of the measures over time.

See figure on the next page for an example of such an impact model, for the specific measure of a green roof strategy.

When developing an impact model from scratch, or from existing adaptation measures, it is useful to work backwards.

Start by precisely defining the long-term **impact**.

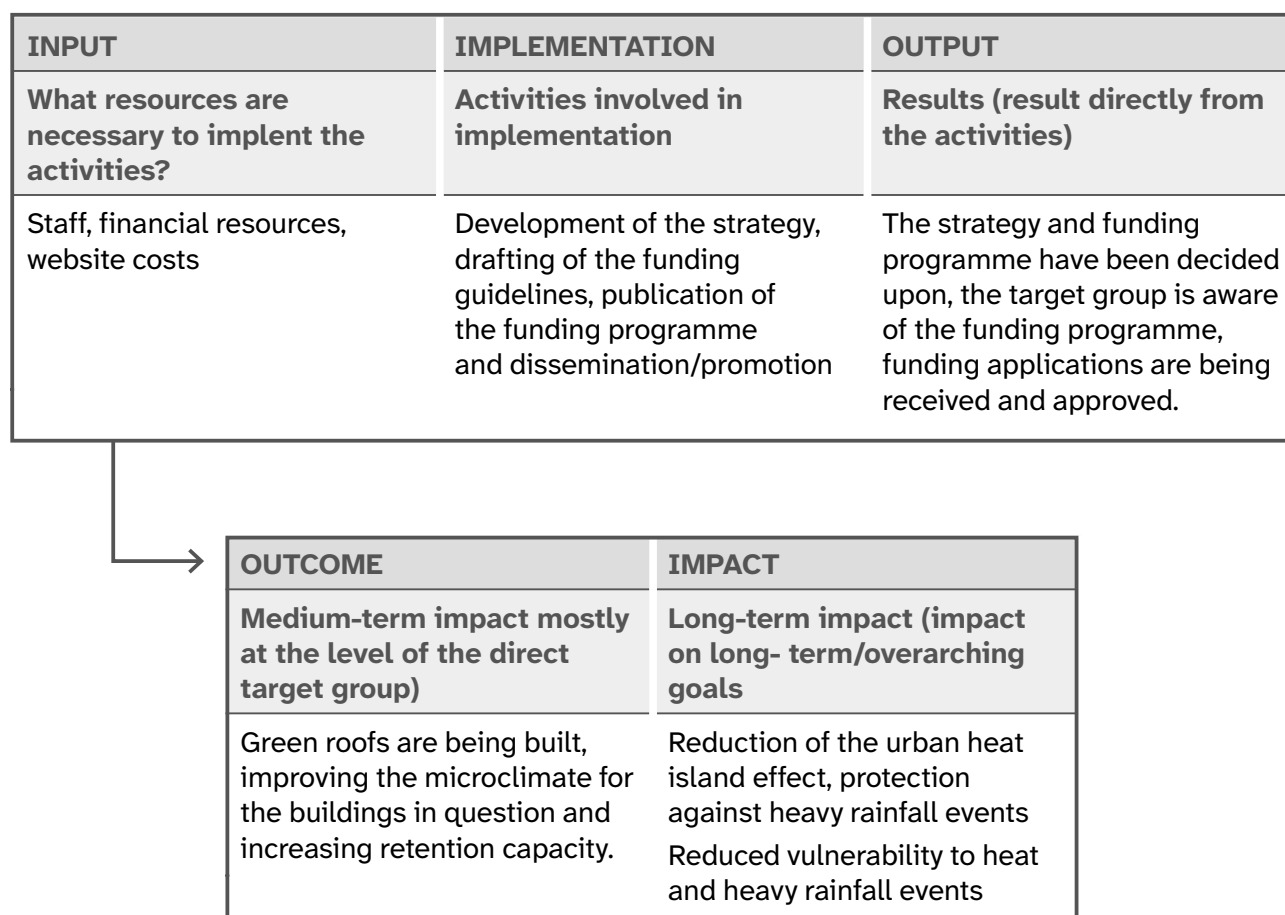
For selecting impacts to be achieved, the results of climate risk assessments can be a good starting point.

Then, list all of the activities or adaptation measures, and identify their immediate short-term **outputs**.

Lastly, define the **outcomes** by bridging the gap between the **outputs** and the **impact** (Rizzi et al. 2025). What are the medium-term effects (**outcomes**) of the **outputs**, which should logically lead to the **impact**?



Impact model based on the green roof example:



Regional-level monitoring:

- » A regional impact model should **capture the complex interactions between multiple measures, sectors and governance levels**. Remember the thematic focus identified in step 1 of section 2.2 and define a few measurable goals, which, if achieved, would be an overarching indicator of adaptation. Considering the regional scope of the evaluation, the impact will inevitably be determined by a multitude of outcomes, spread over multiple sectors and governance levels.
- » For example, in a region which struggles with extreme heat, a reduction in the yearly number of heat-related illnesses would be an overarching indicator of adaptation (impact). This reduction is achieved through multiple mechanisms at the same time: education and awareness, improvement of emergency medical response, improvement in building infrastructure, improvement in green infrastructure, etc.

Step 3: Identify indicators

The next step is to define the indicators, which will be used to measure the impacts, output and outcomes outlined in the impact model.

The required indicators will depend on what is to be considered in the evaluation: **output**, **outcome** or **impact** (or all three).

Refer to your impact model for guidance on this. What are the expected outputs? How could these be measured?

Indicator examples:

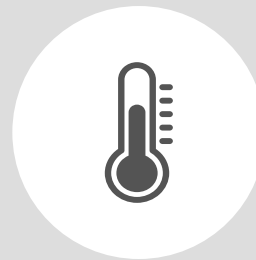
- » **At the output level**, an indicator could be as simple as: Was the measure implemented? Was it implemented within the planned timeframe?

When we consider the impact levels (outcome and impact), it becomes more complex. Let's stick with the green roof strategy example:

- » One **outcome indicator** could be the percentage of buildings with green roofs.
- » An **impact indicator** could be a reduction in the urban heat island effect of X°C by 2035.
- » On the **impact-level** it might help to check, whether there already are matching indicators within existing monitoring-frameworks, or if data is already collected (e.g., data on the urban-heat island effect). Indicators should be reliable and consistent, based on long-term and regular data collection.



Outcome indicators measure direct results (e.g., percentage of buildings with green roofs).



Impact indicators assess broader effects (e.g., reduction in urban heat island temperature).

The selection of data sources and indicators should incorporate the expertise of relevant stakeholders and data providers. Involving these groups – through workshops, bilateral discussions, or focus groups – ensures data availability and supports the development of an efficient, manageable system.

An effective way to advance is by choosing and applying SMART indicators: Specific, Measurable, Achievable, Relevant, Time-bound.

SPECIFIC

The indicator clearly defines what is being measured, avoiding ambiguity.

MEASURABLE

The indicator is quantifiable, allowing progress to be tracked with reliable data.

TIME-BOUND

The indicator specifies a timeframe for achievement, enabling timely assessment.

ACHIEVABLE

The indicator is realistic and attainable, given available resources and constraints.

**RELEVANT**

The indicator is directly linked to the objectives and meaningful for decision-making.

It is furthermore beneficial to include both **quantitative and qualitative indicators** in monitoring adaptation as they provide complementary insights. By combining both types, monitoring becomes more comprehensive and nuanced, enabling a deeper understanding of not only what is changing, but also why and how adaptation measures are affecting communities and systems.



Quantitative indicators provide measurable, objective data to track progress.

Qualitative indicators capture context, perceptions, and experiences.

Step 4: Set Baseline and Targets

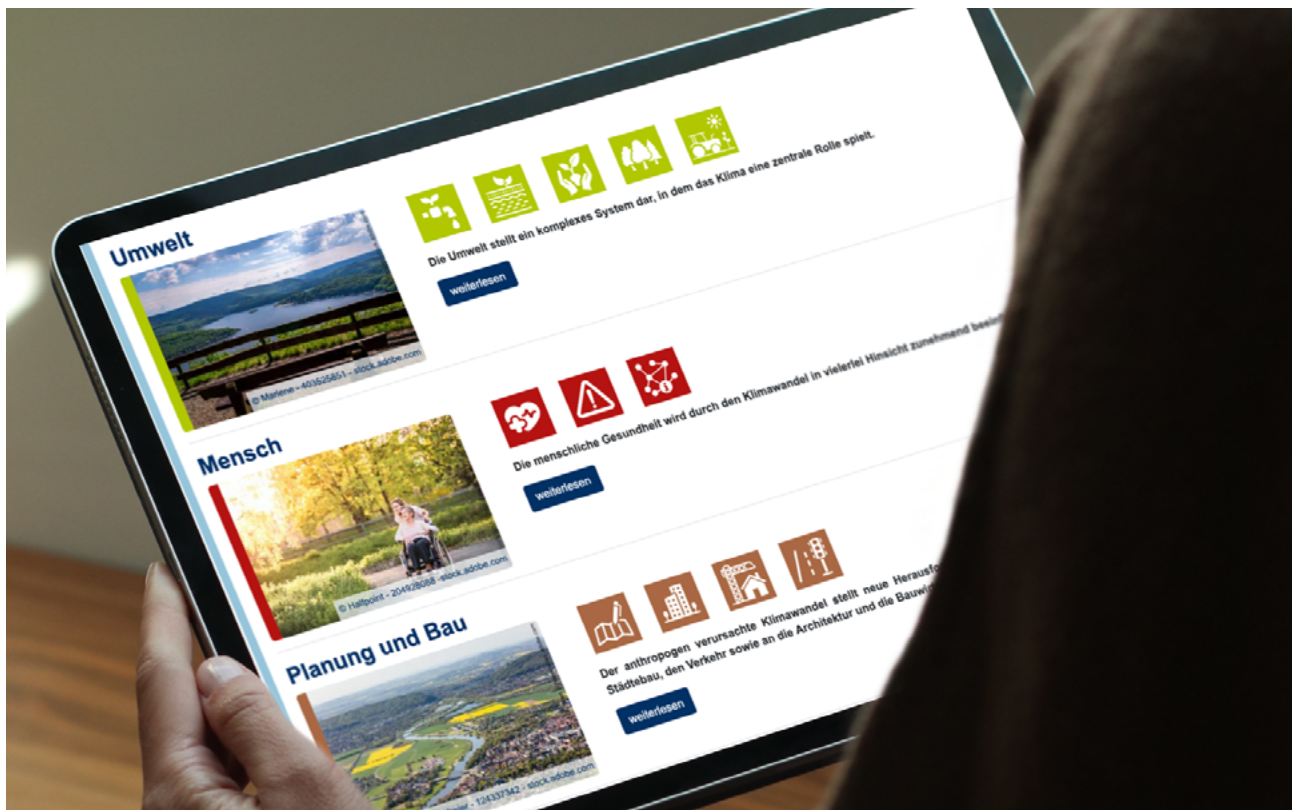
When it comes to starting the monitoring process, it is important to collect baseline data for the indicators for establishing a starting point and to ensure that data sources and methods are consistent and reliable over time.

Returning to our example of the green roof strategy: before we start, we should determine what percentage of roofs are already green roofs. We should also collect climate data, e.g. on the urban heat island effect, so that we can detect any changes later on.

Set realistic, context-specific targets for each indicator (e.g., what is our target percentage of green roofs in the area?), and involve relevant stakeholders in the process to enhance acceptance and transparency.

Regional-level monitoring:

- » On a regional level it is much harder to set a baseline and targets, as there are sectoral interactions and other influences that have to be accounted for.



Picture: Monitoring North Rhine-Westphalia (Germany) practical example. Climate Impact and Adaptation Monitoring in NRW on the screen.

Step 5: Set up Data Collection and Management

Depending on the selected indicators: Start with what you have – use a variety of data sources and collection methods that are both feasible and reliable, such as surveys, interviews, remote sensing, or administrative data. Establish clear protocols and conduct regular quality checks to ensure data consistency and accuracy. Document all data collection procedures to support transparency, reproducibility, and future evaluation. Ensure that the data collected allows for attribution of observed changes to your interventions as much as possible, and plan for regular updates and secure management of all data if manageable.

Mixed methods:



Quantitative

Provides objective, measurable data to track changes over time and compare against baselines, such as temperature, flood damages, crop losses.

Qualitative data

Captures perceptions, experiences, and social dynamics, such as stakeholder interviews, Living Labs, community workshops.

Engages communities, increases data coverage, and enhances engagement e.g. with apps, online questionnaires.

Citizen science



Regional-level monitoring:

- » Consider that the data necessary for computing the indicator will come from various agencies, who might not gather data using the same methodology or labelled “adaptation” or “climate resilience”.

Step 6: Analyse, Prepare Results, and Communicate

ANALYSE

Once the data has been collected, analysis of the collected data is essential to determine whether observed changes can be attributed to specific adaptation interventions rather than external factors.

This requires distinguishing between outcomes resulting from your measures (intended and unintended) and those due to broader climate trends or socio-economic developments for which specifically the combination of both quantitative and qualitative data can be helpful (Dinshaw et al. 2014).



Picture: Mockup of the European Drought Observatory



Picture: 2025 EU Climate Pact Annual Event, ©REGILIENCE

PREPARE RESULTS

For specific methods and the combination of analyses methods (such as econometrics/ statistics, participatory methods, iterative methods and qualitative social science methods), check existing monitoring frameworks and examples from Chapter 4.

Clearly document assumptions, limitations, and uncertainties in the analysis, and engage stakeholders in interpreting the results to ensure that contextual factors and local knowledge are appropriately considered.

COMMUNICATE

Then prepare and present the findings in an easy-to-understand format and share them with the relevant stakeholders.

Use the results to inform decision-making and adjust or improve measures as needed to ensure ongoing effectiveness and resilience.

Transparent communication of results builds trust and accountability and encourages shared learning among everyone involved.



Picture: 2024, ©REGILIENCE



Picture: Green roof in Switzerland. ©Albatros Aslan, Unsplash

To ensure that the results inform policy and practice, communicate the findings in a timely manner and in a way that is tailored to the different target groups, such as policymakers, practitioners or the general public.

Engage stakeholders throughout the process, openly discuss preliminary results, and use a variety of communication methods, such as visuals or tailored messages, to raise awareness and build capacity.

Being transparent about the use of monitoring results from the outset and drawing on lessons from related policy areas helps to keep adaptation a priority and supports continuous improvement.

Regularly reviewing and updating measures based on evaluation findings ensures that adaptation efforts remain relevant and effective over time.

Monitoring in Practice: Key type measures

Climate adaptation measures often generate spillover effects - both positive and negative - beyond their immediate area of implementation. Monitoring at (bio-) regional scale can help identify such cross-boundary impacts, trade-offs, and synergies, supporting adaptive management and policy coherence (Leitner et al. 2021).

Regional monitoring frameworks must therefore integrate indicators and data from all key types to capture this multifaceted nature of territorial resilience.

To simplify monitoring, key type measures were initially developed for the EU Floods Directive and were then adapted for effective reporting of National Adaptation Strategies, Plans and Strategic Action plans on EU level (Leitner et al. 2021). These can also hold value for regional monitoring and can be a step towards comparability amongst different regions.

Let's look at a new example:

Monitoring of climate resilience in a water catchment area.

The example illustrates how an integrated approach can be operationalised and monitored across key type measures:

- » Governance measures that coordinate water management across municipalities
- » Economic measures that incentivise water-efficient practices
- » Physical measures such as flood defences and early warning systems (interconnectedness)
- » Nature-based solutions like wetland restoration (on landscape-scale)
- » Knowledge measures that build community awareness of flood risks

In this chapter, we will attempt to identify the specific features and challenges that need to be taken into account when monitoring certain key types measures (according to the categorisation of adaptation options of the EU Climate Adapt Platform):

- » [Governance and institutional measures](#), page 23
- » [Economic and finance measures](#), page 24
- » [Physical and technological measures](#), page 25
- » [Nature-based solutions and ecosystem-based approaches](#), page 26
- » [Measures focusing on Knowledge and Behavioural change](#), page 27.

GOVERNANCE AND INSTITUTIONAL MEASURES	
Description	Governance and institutional adaptation measures aim to strengthen frameworks, processes and capacities that support decision-making and coordination for climate adaptation. They help create an enabling environment by establishing institutional arrangements, ensuring policy coherence and involving stakeholders. This often includes reforming legal and regulatory systems, building the capacity of public institutions, and setting up mechanisms for inclusive planning and coordination across sectors and levels of government.
Examples	Adaptation strategies, local adaptation planning, inter-agency coordination bodies, and participatory governance platforms.
Challenges	› Intangible and Qualitative Nature: Governance and institutional changes – such as improved coordination, policy coherence, or stakeholder engagement – are often qualitative and less tangible than physical outputs, making it harder to measure and track them. › Attribution: It is difficult to attribute improvements in adaptation outcomes directly to governance reforms, as progress often results from a combination of factors and overlapping initiatives. › Long Timeframes: Institutional and governance changes typically take time to create an effect, and their impacts may only become visible over the long term, beyond the duration of typical monitoring cycles. › Data Availability and Reliability: Data on governance processes, institutional arrangements, or stakeholder participation may be limited, subjective, or inconsistently reported. › Political Sensitivity: Monitoring governance reforms can be politically sensitive, as it may touch on issues of power, accountability, or institutional performance.
Recommendations	› Use Mixed Methods and Qualitative Approaches: Combine quantitative indicators (e.g., number of policies adopted, frequency of coordination meetings) with qualitative methods (e.g., interviews, surveys, case studies) to capture both tangible and intangible changes. › Monitor Intermediate Outcomes: Track not only final outcomes but also intermediate steps – such as improved communication, increased stakeholder participation, or enhanced institutional capacity – that signal progress in governance. › Ensure Stakeholder Participation: Engage stakeholders in designing and conducting monitoring. This increases ownership, relevance, and the likelihood of collecting honest and nuanced information. › Plan for Long-Term Monitoring: Recognise that governance changes take time. Where possible, establish monitoring systems that can track progress over several years. › Triangulate Data Sources: Use multiple sources of information (e.g., official reports, third-party assessments, direct observation) to validate findings and reduce bias. › Address Political Sensitivity: Approach politically sensitive topics with care, using neutral language and ensuring confidentiality where needed to encourage honest feedback. › Foster Learning and Adaptation: Use monitoring not just for accountability, but as a tool for learning and continuous improvement – encouraging institutions to reflect on progress and adapt as needed.

ECONOMIC AND FINANCE MEASURES	
Description	Economic and Finance measures focus on enhancing resilience to climate change by leveraging financial instruments, economic policies, and market-based solutions. These measures aim to reduce vulnerability, allocate resources efficiently, and incentivize sustainable practices. They involve creating financial mechanisms, adjusting economic systems, or providing support to communities and businesses to adapt to changing environmental conditions.
Examples	Measures can be diverse and include financing incentive instruments such as subsidies and grants, tax incentives, green bonds, as well as insurance and risk sharing instruments such as climate risk insurance, microinsurance, risk pools.
Challenges	› Complex financial flows: Funds may flow through complex channels and be used for multiple purposes, making it challenging to track exactly how resources are allocated and spent on adaptation. › Attribution of Outcomes: It is often difficult to directly link financial investments to specific adaptation outcomes, as many external factors can influence results. › Comparing Inputs and Outcomes: It can be challenging to compare the scale of financial inputs with the adaptation outcomes achieved, particularly when qualitative benefits (e.g., increased resilience) are involved. › Overlapping Objectives: Economic and finance measures often serve multiple policy objectives (e.g., development, disaster risk reduction, adaptation), making it hard to isolate the adaptation-specific impacts. › Exchange Rate and Inflation Risks: Financial values can fluctuate due to exchange rates or inflation, complicating long-term tracking and comparison.
Recommendations	› Strengthen Tracking and Reporting Systems: Develop clear protocols and tools for tracking financial flows, allocations, and expenditures specifically for adaptation. Use dedicated budget lines or tagging systems to distinguish adaptation finance from other spending. › Use Mixed Methods for Evaluation: Combine quantitative data (e.g., financial reports, cost-benefit analyses) with qualitative approaches (e.g., stakeholder interviews, case studies) to capture both tangible and intangible benefits. › Adjust for Economic Fluctuations: Account for inflation and exchange rate changes in financial reporting to ensure accurate long-term comparison. › Disaggregate Data: Where possible, break down finance data by sector, region, or beneficiary group to better understand where resources are going and who is benefiting.

PHYSICAL AND TECHNOLOGICAL MEASURES	
Description	Physical and Technological measures involve the development, implementation, or modification of grey infrastructure and technologies to reduce vulnerability to climate change impacts. Measures aim to protect people, assets, and ecosystems by enhancing physical resilience and enabling adaptive responses through technological and technical innovation and engineering.
Examples	Measures may include traditional infrastructure such as seawalls, irrigation systems, flood barriers, and emerging technologies such as climate-smart agriculture tools, early warning systems, or water-efficient technologies. Measures are often context-specific and may vary by sector and location.
Challenges	› Quantifying Effectiveness: While it is often easier to track the implementation of physical or technological measures (e.g., kilometers of dykes built, sensors installed), it can be difficult to measure their actual effectiveness in reducing climate risks or improving resilience. › Maintenance and Sustainability: Physical and technological solutions require ongoing maintenance and regular updates. Monitoring systems need to assess not just initial implementation, but also long-term functionality and sustainability. › Data Availability and Quality: Technological measures may generate large amounts of data, but ensuring the quality, consistency, and relevance of this data for adaptation monitoring can be difficult. › Social and Equity Considerations: Monitoring often focuses on technical performance, while overlooking whether the measures are accessible, beneficial, and safe for all social groups, including vulnerable populations.
Recommendations	› Combine Output and Outcome Indicators: Monitor not only what has been built or installed (outputs), but also how well these measures perform in practice (outcomes) – for example, by tracking reduction in damages or disruptions during climate events. › Establish Clear Baselines and Attribution Methods: Collect baseline data before implementation and use control sites or comparative methods to better attribute observed changes to the specific measure. › Plan for Long-Term Monitoring and Maintenance: Include provisions for regular inspections, maintenance, and updates in the monitoring plan to ensure ongoing functionality of physical and technological solutions. › Integrate Social and Equity Indicators: Include indicators that assess whether all groups benefit from the measures, paying particular attention to vulnerable populations and potential unintended consequences.

NATURE-BASED SOLUTIONS (NBS) AND ECOSYSTEM-BASED APPROACHES	
Description	Nature-based solutions and ecosystem-based approaches harness the power of biodiversity and ecosystem services to build resilience to climate change impacts. They aim to reduce climate risks while delivering co-benefits for people and nature by protecting, sustainably managing, or restoring ecosystems. A key benefit is the ability to address multiple challenges simultaneously.
Examples	Nature-based solutions for climate change adaptation include restoring wetlands to absorb floodwaters and creating urban green spaces to mitigate heatwaves. Ecosystem-based approaches also involve reforestation degraded landscapes to stabilise soils and protect against landslides, as well as preserving coastal dunes and mangroves to buffer communities from storm surges.
Challenges	› Complexity and multi-functionality: NbS often deliver multiple benefits simultaneously (e.g., biodiversity, water regulation, recreation), making it difficult to capture the full range of outcomes with standard indicators. › Long Timescales: Ecosystem responses and benefits may take years or even decades to become apparent, which does not always align with project or funding cycles. › Attribution: It can be challenging to attribute observed changes in ecosystems or climate resilience directly to specific interventions, as natural systems are influenced by many external factors (e.g., weather, land use changes, upstream activities). › Baseline Data and Reference Conditions: Reliable baseline data on ecosystem conditions are often lacking, making it hard to measure change or improvement over time. Natural variability also complicates the identification of clear reference points. › Monitoring at Appropriate Scales: Ecosystem-based measures often operate at landscape or watershed scales, requiring monitoring approaches that can capture changes across large, heterogeneous areas.
Recommendations	› Develop Integrated and Flexible Monitoring Frameworks: Design monitoring systems that capture multiple benefits (e.g., ecological, social, economic) and can be adapted as new knowledge emerges. Use a combination of indicators to reflect the multifunctionality of NbS. › Plan for Long-Term Monitoring: Where possible, secure resources and partnerships for monitoring over extended periods, so that long-term ecosystem changes and benefits can be captured. › Strengthen Baseline Data Collection: Invest in robust baseline studies before interventions begin. Use historical data, remote sensing, and participatory mapping to establish reference conditions. › Use Appropriate Spatial Scales: Apply monitoring methods suited to the scale of the intervention (e.g., landscape, watershed). Remote sensing, GIS, and citizen science can help cover large areas efficiently. › Combine Scientific and Local Knowledge: Integrate local, traditional, and scientific knowledge in monitoring design and data interpretation. This can improve relevance, acceptance, and understanding of observed changes. › Use Cost-Effective Tools: Leverage technologies such as drones, remote sensing, and mobile apps to reduce costs and increase data collection efficiency.

KNOWLEDGE AND BEHAVIOURAL CHANGE

Description	Knowledge and behavioural change measures aim to enhance adaptive capacity by fostering awareness, building skills, and encouraging shifts in attitudes, practices, and decision-making related to climate change adaptation. These measures focus on empowering individuals, communities, and institutions to make informed choices and take proactive steps toward resilience to climate change impacts.
Examples	They can include climate education, training programs, public awareness campaigns and the promotion of adaptive behaviour.
Challenges	› Intangible and gradual changes: Knowledge and behaviour are not as easily measured as physical outputs or financial flows. Changes often happen gradually and may not be immediately visible. › Attribution difficulties: It can be difficult to attribute observed changes directly to specific adaptation measures, as knowledge and behaviour are influenced by many factors (e.g., media, peer groups, previous experiences). › Measuring depth and quality: It's challenging to assess not just whether people have gained knowledge, but how deeply they understand it and whether it leads to meaningful, lasting behavioural change. › Reliance on self-reporting: Monitoring often depends on surveys or interviews, which can be biased or unreliable, as people may overstate their knowledge or intended actions. › Long timeframes: Changes are often intangible, gradual, and influenced by many factors, making them difficult to measure, attribute, and track reliably.
Recommendations	› Use mixed methods: Combine quantitative (e.g., surveys, quizzes) and qualitative (e.g., interviews, focus groups, case studies) methods to capture both the extent and depth of change. This helps to triangulate findings and reduce bias. › Develop clear, context-specific indicators: Design indicators that are tailored to the local context and specific target groups. For example, instead of simply measuring "awareness," focus on specific knowledge or behaviour relevant to the adaptation goal. › Incorporate Participatory Approaches: Engage stakeholders and beneficiaries in designing and implementing the monitoring process. This increases relevance, ownership, and the likelihood of honest responses. › Monitor Intermediate Outcomes: Track not only ultimate behavioural change, but also intermediate steps (e.g., changes in attitudes, intentions, skills) to capture progress along the way. › Address Bias in Self-Reporting: Use anonymous surveys or triangulate self-reported data with other sources (e.g., observation, third-party reports) to improve reliability.

Examples from regions and of other existing indicator frameworks

The following sections present concrete examples of climate adaptation monitoring currently implemented across European regions, alongside established resilience frameworks that can inspire your own indicator development. First, we showcase regional resilience and adaptation plans with integrated monitoring systems, ranging from comprehensive indicator frameworks to qualitative approaches. In the second section, we review existing resilience monitoring frameworks that offer robust methodologies for climate change resilience and adaptation monitoring.

Examples on how monitoring is already covered in regional adaptation plans

Climate Impact and Climate Adaptation Monitoring North Rhine-Westphalia, Germany

The [Climate Impact and Climate Adaptation Monitoring NRW](#) (KFAM NRW) represents one of Germany's most comprehensive regional approaches to tracking climate change effects and adaptation responses. Building upon the Climate Impact Monitoring NRW established in 2011, this framework has been continuously expanded and updated to provide a robust foundation for evidence-based climate monitoring.

METHODOLOGY

The KFAM NRW employs a systematic approach based on the DPSIR model (Drivers, Pressures, State, Impact, Response) developed by the OECD and adopted by the European Environment Agency. This model describes the sequence of relationships between influencing factors and environmental effects in the context of anthropogenic climate change.

The framework is structured around five main clusters – “Climate”, “Environment”, “Human”, “Planning & Construction”, and “Economy” – which aggregate the 16 action fields defined in NRW's Climate Protection Plan.

INDICATORS

To ensure comprehensive coverage, 200 potential indicators were initially examined, including those from existing German and international monitoring systems. This comprehensive review aimed to identify indicators that could be used in NRW whilst maintaining compatibility with broader monitoring efforts.

Expert consultations played a crucial role in the selection process, involving practitioners, scientists, and representatives from the Ministry for Environment, Agriculture, Nature and Consumer Protection of North Rhine-Westphalia (MULNV) and other government departments.

These consultations helped identify additional suitable indicators and ensured that the final selection was both scientifically sound and practically applicable. Of the 200 indicators initially examined, 79 were selected for current implementation (categorised as impact, state and response indicators).

An additional 31 indicators were reserved for future inclusion once current limitations – such as data availability or methodological challenges – are resolved. The remaining indicators were excluded due to various factors, including overly complex causal relationships with climate change or lack of available data.

Strengths: The approach demonstrates exceptional thoroughness through its transparent, multi-sectoral process involving diverse stakeholder groups and policy levels, whilst the DPSIR methodology facilitates effective knowledge transfer. The comprehensive website provides a very sound indicator presentation with clear progress tracking transparent for all.

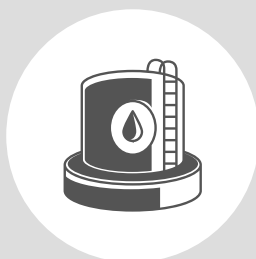
Shortcomings: The lengthy development process and high exclusion rate of initially selected indicators (nearly 45%) may limit the system's comprehensiveness and delay implementation of important monitoring components.



State indicators describe climate development in NRW itself, tracking fundamental climate variables such as temperature and precipitation patterns



Impact indicators capture the effects of climate change, including phenomena like soil drought and changes in groundwater balance



Response indicators document adaptation measures and activities that support the adaptation process, representing a significant innovation as these were not included in the earlier climate impact monitoring system

Global Indicator of Climate Change Adaptation in Catalonia, Spain

Another example is the Global Indicator of Climate Change Adaptation in Catalonia. It was established under the 2012 Catalan Strategy for Adapting to Climate Change (ESCACC) and monitors adaptive capacity across ten key sectors using 42 quantitative indicators. Selection is based on annual data availability and historical records.

METHODOLOGY

A distinctive feature of the Catalan approach is the use of principal component analysis (PCA) to aggregate indicators into an index reflecting resource use and environmental quality, providing a structured approach to track and assess adaptation progress in the region every 5–10 years.

INDICATORS

The selection process focused on identifying indicators that could quantitatively measure the outcomes of adaptation actions, prioritising those capable of evaluating the effectiveness of implemented measures. Indicators that only assessed sectoral sensitivity or exposure were excluded, while both quantitative outcome-based and certain qualitative planning indicators were retained. By this methodology, the initial list of 83 indicators was narrowed down to 50.

To ensure the robustness of the monitoring system, only indicators with at least ten consecutive years of historical data were included. This rigorous criterion narrowed the list to 29 indicators (Agell et al. 2016). Since its inception, the indicator set has been regularly updated to reflect new challenges and priorities, which is why there are now 42 indicators in total (Catalan Office for Climate Change 2019). [The most recent update](#) (2024) introduced indicators related to climate justice, highlighting a growing recognition of the social dimensions of climate adaptation in Catalonia (Catalan Office for Climate Change 2024).

Strengths: The PCA methodology enables Catalonia to provide a clear quantitative assessment of overall adaptation progress, whilst regular updates ensure that emerging priorities and new topics are acknowledged and incorporated into the framework.

Shortcomings: The requirement for 10 years of historical data may exclude important emerging adaptation measures that lack sufficient historical records, and the relatively infrequent monitoring cycles may miss rapid changes requiring timely responses.

Other examples

The [Gran Canaria adaptation strategy](#) (Grupo Considera 2021) includes a dedicated monitoring section, featuring general indicators divided into Monitoring and Performance indicators. Rather than providing detailed indicators for each individual measure, the plan focuses on broader metrics. For example, within the area of emergency and warning systems, the number of days with heat waves serves as a Monitoring indicator, while deaths due to excessive heat are tracked as a Performance indicator.

Strengths: The focus on broader metrics creates a manageable framework that avoids overwhelming complexity whilst still capturing essential adaptation outcomes, making it practical for implementation.

Shortcomings: This broader approach lacks the detail needed to pinpoint specific successes or failures within the strategy, which may limit opportunities for targeted improvements.

The [Austrian planning region east](#) (PGO) published a report on how the planning region of eastern Austria, specifically Burgenland, Lower Austria and Vienna, can become more resilient. The report also contains concrete monitoring indicators for regional climate proofing measures, such as the proportion of green spaces in settlement areas, the number of exposed buildings in natural hazard risk zones, the amount of sealed area, as well as the type of land take (Jiricka-Pürrier et al. 2021).

Strengths: The Austrian regional approach is a great example for providing a good description of a process and it provides indicators directly linked to physical adaptation measures.

Shortcomings: The focus on spatial planning and physical infrastructure indicators risks overlooking crucial social and economic dimensions of climate resilience needed for comprehensive adaptation monitoring.

Resilience monitoring frameworks for inspiration

There are many detailed guidance documents that can also serve as inspiration. A summary, including usability ratings, can be found in the REGILIENCE Living Document (Kind and Bilgram 2023). In the following, we provide a curated overview of some frameworks.

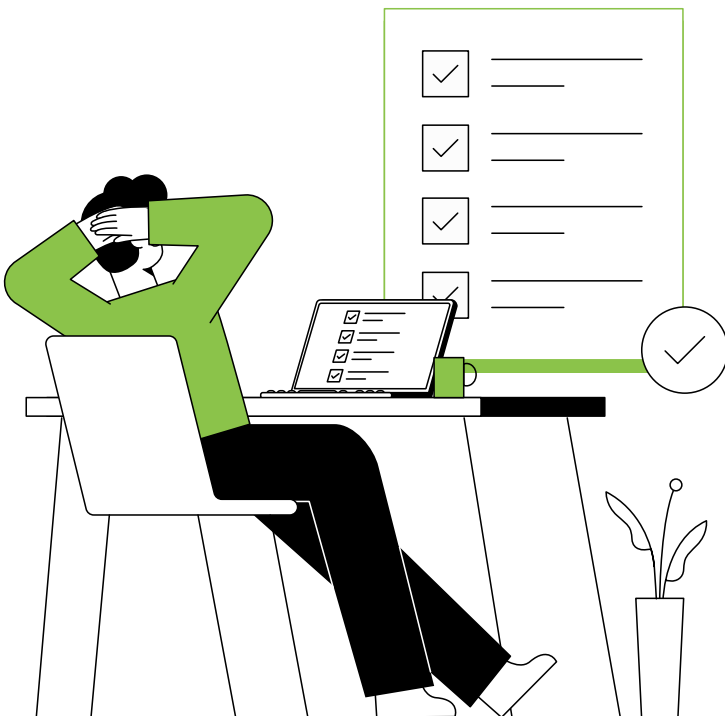
IMPETUS Resilience Metrics	The IMPETUS indicator framework offers a flexible, multi-scale and cross-sectoral set of indicators for assessing climate vulnerability and adaptation, designed to be adaptable to different European contexts and scales, and to be continuously improved through practical application (Koop et al. 2022). Strengths: » Specifically designed for climate resilience monitoring, thoroughly assesses existing frameworks, and covers climate vulnerability, adaptation, and resilience as core pillars. » The indicator set is flexible and adaptable, with both core and additional indicators, and will be tested in practice within the project. Weaknesses: Data compilation can be difficult as it does not rely on publicly available data.
EU Sustainable Development Goals Framework	The framework is widely accepted and supports climate resilience by addressing interconnected sustainability goals; its main strengths are broad acceptance and existing national data, but limited regional data can be a drawback. Strengths: » The SDGs offer a comprehensive framework covering a wide range of sustainability issues and their interconnections. » They are globally recognised, promoting consensus and coordinated action across all decision-making levels. Weaknesses: » The SDGs are not specifically designed to measure climate resilience, making it difficult to capture its specific aspects. » They often lack region-specific data, which can limit their usefulness for assessing local climate resilience.

Smart Mature Resilience Model	The SMART Resilience Maturity Model helps cities assess and advance their overall resilience through defined maturity stages and dimensions, offering a strategic roadmap for involving stakeholders and guiding resilience planning – not limited to climate resilience. Strengths: The Resilience Maturity Model is flexible and can be adapted to any city's and to a certain extent regions' current resilience level, with clear descriptions and well-defined indicators. Weaknesses: It is designed for general, not climate-specific, resilience, making it less suitable for capturing climate resilience details. Its use is mainly limited to cities with the necessary infrastructure and governance.
OECD Resilient Cities Framework	This framework supports cities, and to a limited extent regions, in selecting and using social, economic, environmental, and institutional indicators for monitoring resilience, with an emphasis on local adaptation and public participation, but it is not specifically focused on climate resilience (Figureido et al. 2018). Strengths: Clear guidance and recommendations for authorities on how to choose tailored indicators for their specific purpose (section 2.6.). Weaknesses: » Not specifically targeted towards climate resilience. » Targeted towards cities with limited applicability to regions.
ISO Indicators Sustainable Cities and Communities – Resilient Cities	ISO 37123 provides a standardised set of indicators for cities (partly applicable to regions) to consistently measure and improve their resilience across areas like environment, economy, health, and governance, helping them better prepare for and respond to various shocks and challenges (ISO 2019). Strengths: » ISO 37123 is a standardised, internationally recognised framework that supports transparency, accountability, and certification. » Its indicators and guidelines assist decision-making and the development of resilience strategies. Weaknesses: » Not specifically developed for regions or focused solely on climate resilience as its main focus is on general resilience. » Data collection can be difficult. » Standard must be purchased.

Conclusion

Monitoring regional climate change adaptation is a dynamic, iterative process that requires careful planning, inclusive collaboration, and a willingness to learn and adapt along the way.

The steps outlined in this report provide a structured foundation for practitioners and decision-makers to design, implement, and refine robust monitoring frameworks tailored to their regional needs.



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About this publication

Effective climate adaptation requires more than action: it demands systematic monitoring to track progress, inform decisions, and build resilience.

This guide provides a structured, step-by-step approach to monitoring regional climate change adaptation, from defining clear objectives and selecting SMART indicators to building comprehensive monitoring frameworks that capture both immediate results and long-term impacts.

Monitoring regional climate change adaptation is a dynamic, iterative process that requires careful planning, inclusive collaboration, and a willingness to learn and adapt along the way. The steps outlined in this report provide a structured foundation for practitioners and decision-makers to design, implement, and refine robust monitoring frameworks tailored to their regional needs.

Whether you're assessing green infrastructure measures, tracking vulnerability reduction across sectors, or coordinating multi-level governance responses, this publication offers practical guidance to ensure your adaptation efforts are accountable, evidence-based, and continuously improving.

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