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Recommendations for climate smart indicators and criteria for resilient tourist beaches in the BSR

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Introduction

The report contributes to the project BEACH-SOS, which aims to support authorities, businesses, and local coastal communities adapting to climate change to ensure the long-term sustainability and vitality of beach recreation and tourism.

The project seeks to guide and support local municipalities in understanding and applying climate change information in their coastal management to better care for their beaches. A key goal of this project is to ensure that reliable and accessible information is available to all stakeholders to help navigate the challenges posed by a changing climate.

The report is structured as follows. The first section provides background information on “climate-smart” indicators and the methodology used in their selection and evaluation. The second section presents the results, covering physical and social aspects. The third section offers recommendations for the selected indicators selected indicators to be included in future oriented adaptation processes. In particular, the consideration and inclusion of the indicators developed in the Blue Flag system offers great potential for the adaptation process of coastal communities. The report provides guidance on how the indicators can be taken into account.

Indicators

Indicators are measurable variables or sets of variables that provide information about the state, trend, or performance of a system in relation to specific objectives. Basically, indicators simplify complex phenomena into understandable and actionable information *(Heink & Kowarik, 2010).* According to the OECD (2001), an indicator "quantifies and simplifies phenomena and helps us understand complex realities." Indicators are widely used in many aspects of daily life—for example, body temperature is an indicator of health, GDP is an indicator of economic performance, and weather forecasts rely on environmental indicators like temperature, humidity, and wind speed. In sustainability and environmental management, indicators are essential tools for monitoring progress, informing decision-making, setting targets, and communicating trends to stakeholders and the public (United Nations, 2007). They allow policymakers and practitioners to assess the effectiveness of measures, identify emerging issues, and allocate resources efficiently. In the context of beach tourism and climate adaptation, indicators help communities to track ecological and socio-economic changes, understand vulnerabilities, and design targeted strategies to enhance resilience and sustainability.

Beaches are among the most climate-sensitive environments, facing challenges such as sea-level-rise, erosion, and increasingly frequent extreme weather events. Climate change affects not only the physical landscape, but also the ecological balance and socio-economic viability of beach tourism destinations.

Although a wide range of internationally and nationally recognized indicator selection criteria already exist—covering aspects such as economic performance, environmental quality, social well-being, and governance—there remains a lack of specific indicators that directly address the pressures on coastal zones and beaches. This gap hampers the translation of climate-related impacts into practical beach management strategies. In this essence, EUCC- The Coastal Union Germany, as part of the Beach-SOS project, developed a set of indicators specifically designed to capture the impacts of climate change on coastal areas and beaches. These indicators support the monitoring, quantification, and understanding of long-term trends. They encompass a variety of physical and social aspects, providing a comprehensive picture of beach changes. The main objective was to identify and define the most relevant and urgently needed indicators for effectively monitoring and managing climate-related impacts on beaches. By tracking these indicators, local and regional stakeholders can design targeted adaptation strategies to strengthen the climate resilience of both natural ecosystems and tourism-dependent communities in the Baltic Sea Region (BSR).

The indicators are intended for use at both municipal and regional levels. While local governments and tourism managers are on the front line of implementation, successful climate adaptation also requires coordination with regional authorities to ensure policy alignment, funding access, and integrated coastal planning. Ultimately, the indicators are designed as a practical tool to support ongoing evaluation, enable evidence-based decision-making, and improve the long-term resilience and sustainability of coastal tourism across the BSR. They help tailor adaptation strategies to the specific vulnerabilities and capacities of each locality.

Methodology

Three steps were taken to develop and propose "climate smart", realistic and ready to go indicators for the management of tourist beaches (Figure 1).

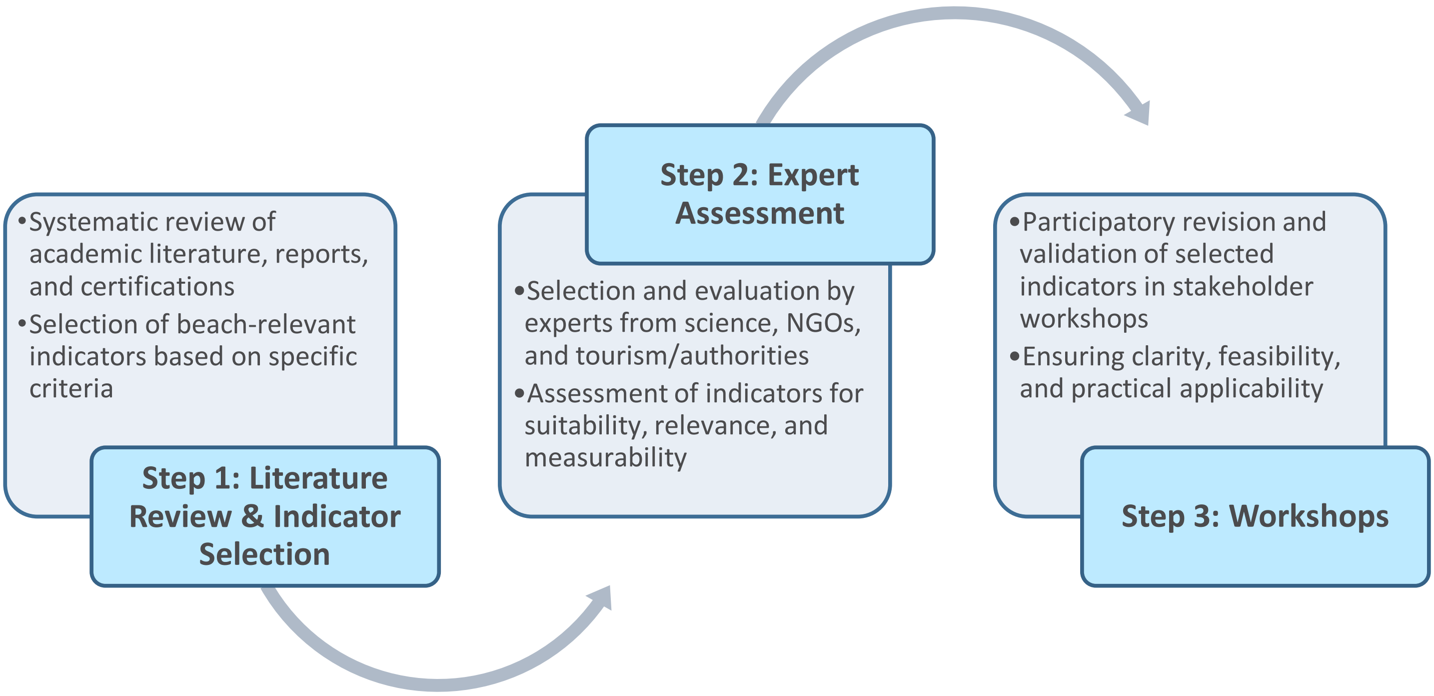

Figure 1: Methodological approach.

Step 1: Literature Review & Indicator Selection

A comprehensive process was undertaken to identify and refine climate change and sustainable tourism indicators:

1. First, a systematic literature review was conducted using academic databases, institutional reports, scientific publications, and tourism certification schemes. This provided a broad and inclusive list of indicators used in the context of climate change, sustainable tourism, and adaptation. In total 666 indicators were collected.
2. Second, from this comprehensive list, indicators relevant to the beach context were selected based on predefined beach-specific criteria. This step ensured that only those indicators applicable to beach tourism and coastal climate impacts were retained.
3. Third, duplicate or overlapping indicators were removed to streamline the list, leading to a total of 50 indicators.
4. Finally, the remaining indicators were organized into two main categories: Physical indicators and socio-economic indicators (Figure 2).

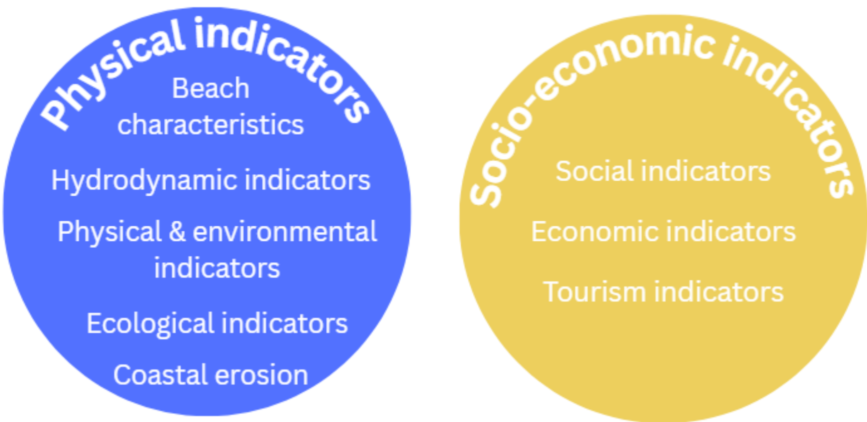

Figure 2: Indicator groups.

Step 2: Expert Assessment

In the second step, the list of 50 beach-relevant indicators was evaluated by a panel of experts representing three key stakeholder groups: science, non-governmental organizations (NGOs), and tourism/authorities.

As part of this expert assessment, each of the 50 indicators underwent a structured and time-intensive review process. The experts carefully evaluated each indicator based on the following three main criteria:

- Suitability
- Relevance
- Measurability

This thorough evaluation served a dual purpose: it helped identify and retain the most appropriate and meaningful indicators for assessing climate change impacts in coastal tourism settings. It also allowed the identification and exclusion of indicators that were less relevant, less practical, or not sufficiently measurable in the beach context. In the end, 34 indicators remained from the previous 50.

Step 3: Workshops

Workshops were held in Germany, Latvia and Denmark with a group of stakeholders - including tourism professionals, beach managers, scientists, NGO representatives, and public authorities. Since reviewing all 50 indicators is not feasible in a workshop setting the participants worked with the 34 pre-selected indicators chosen by the expert panel in the second step. From that list the participants selected the indicators that they considered most important, as it was not possible to address all 34. The selected indicators were then evaluated using SMART criteria (Specific, Measurable, Applicable, Relevant, Time-bound). This step ensured that the indicators were not only relevant but also practical, clearly defined, and suitable for real-world implementation in beach tourism and climate change adaptation efforts. Result sheets from the workshops in Germany can be found in the Appendix.

Figure 3: left: Stakeholder Workshop Warnemuende; right: workshop material

Results

A total of 20 indicators were selected through the participatory processes of the expert assessment (second step) and the stakeholder workshops (third step). Initially, 666 indicators were collected. In the first step, this number was narrowed down to 50 beach-relevant indicators, then to 34 in the second step, and finally to 20 in the third step. Within the workshops there were overlaps in the selection of the indicators. If there were any differences, e.g. in the formulation of the indicators, these are listed. Additionally, one new indicator was developed during the process.

It is important to note that indicators not selected at this stage may still become relevant in the future, and new indicators may be proposed as the context evolves.

Each indicator will be presented with.

- A clear **definition**,
- A **rationale** explaining its relevance to tourism, climate change, and beach environments, and
- A **description of its measurement approach**.

The report will provide a detailed overview of the most relevant indicators, including those prioritized during the workshops. The results of the workshops are presented in fact sheets in Annexes I and II.

1. Physical Indicators

The physical indicators include a variety of aspects: climatic parameters, hydrodynamic aspects, beach characteristics, coastal morphology, ecological indicators (Figure 2). These indicators were consistently identified as highly relevant by stakeholders across both the expert-assessment and workshops, underscoring their importance in capturing the impacts of climate change on beach and coastal environments and consequently, on beach tourism.

Ind. 1.1: Storm surges

- **Definition:** Changes in current conditions, tidal dynamics and storm surges *(Umweltbundesamt., 2011, 2024).*
    - **Own definition:** Changes in environmental conditions, such as water movement and the occurrence of storm-induced flooding.
    - **Workshop Germany:** Occurrence of storm surges, i.e. extreme flooding caused by storms (from 1.5 m above mean high water) and height (maximum level in one year).
- **Rationale:** Storm surges are increasing due to climate change, driven by sea-level rise and more frequent extreme weather events. These events can result in/cause flooding, damage to beach infrastructure, and directly disrupt tourism and beach use. The heightened risk affects both visitor safety and the economic viability of tourism-dependent coastal region.
- **Measurement:**
    - Number of storm surges events/defined events, height and number. At the German Baltic coast four level of storm surges are distinguished*:*

Storm surge	1.00-1.25 m above mean sea level
Medium storm surge	1.25-1.50 m above mean sea level
Severe storm surge	1.50-2.00 m above mean sea level
Very severe storm surge	more than 2.00 m above average water level

    - Forecasts are based on a combination of water level observations, wind measurements and meteorological forecasts as well as the results of an operational hydrodynamic model system. The forecasts indicate the time and height of the expected water level for the next 6 days in various regions along the coast (*Federal Maritime and Hydrographic Agency (BSH), 2024)*.
    - *Damage on the beach and beach infrastructure.*
    - *Extent of the impacted area measured in square kilometers.*
    - *Economic damage measured in local currency.*

Ind. 1.2: Storms

- **Definition:** Number of storms events in the last 10 years *(Toubes et al. 2017).*
    - **Own definition:** Frequency and intensity of storms over a specific period.

- **Rationale:** Stronger and more frequent storms due to climate change cause coastal flooding and erosion. Damage beach infrastructure e.g. beach bars, beach chairs, boardwalks, reduce safety for tourists and possibly reduce beach attendance therefore affection of tourism revenue. Decrease the visual, recreational quality and usability of the beach, undermining its attractiveness for visitors.

Beau-fort	Wind Speed (km/h)	Wind Description	Wave height (m)	Sea Conditions
6	39–49	Strong breeze	3	Large waves, white foam crests
7	50–61	Near gale	4	Sea heaps up, spray
8	62–74	Gale	5.5	Moderately high waves
9	75–88	Strong gale	7	High waves, foam streaks
10	89–102	Storm	9	Very high waves, poor visibility
11	103–117	Violent storm	11.5	Exceptionally high waves
12	≥118	Hurricane force	14+	Massive waves, air full of foam

- **Measurement:**
  - Number of defined events throughout the year and/or season. A storm is designated for wind of great intensity, classified according to the Beaufort scale.

  Source: Deutscher Wetterdienst (n.d.).

  - *Damage on the beach and beach infrastructure.*
  - *Extent of the impacted area measured in square kilometers.*
  - *Economic damage measured in local currency.*

Ind. 1.3: Sea-level rise

- **Definition:** Increasing in the level of the sea in x year *(Toubes et al. 2017).*
  - **Own definition:** Change in sea level over time
- **Rationale:** Rising sea levels poses risks/threats to coastal tourism infrastructure, beaches, and natural attractions. This increase can lead to more frequent and severe flooding, erosion, and loss of habitat, directly impacting (beach) tourism and local communities. Understanding and monitoring

sea-level rise is essential for developing effective coastal management and protection plans to safeguard these valuable resources.

- **Measurement:**
  - Increase in the average height of the sea surface in relation to a specific point on land or to a global reference point.
  - Millimetre or centimetre per year.
  - Measuring stations show how the sea level is changing in relation to the land at a local level. Satellites measure how the height of the entire ocean changes. Together, this shows how high the sea level is today and how it has changed over time *(IPCC, 2021).*

Ind. 1.4: Loss of beach area

- **Definition:** Loss of beach area at the end of the century (2080–2100) with respect to the current available area (2000–2020), due to mean sea level rise *(Agulles et al., 2022).*
  - **Own definition:** Loss of beach areas caused by changes in water levels.
- **Rationale:** Beach area loss, driven by sea-level rise and increased erosion, reduces space for recreation and damages natural appeal. It directly impacts tourism potential and coastal economies, making it a visible and measurable sign of climate change.
- **Measurement:**
  - Change in beach area measured in square meters (m^2) or as a percentage loss relative to a baseline period.
  - Utilizes time-series satellite imagery to detect shoreline and beach changes over time.
  - Beach area is digitized and analyzed using mapping and geospatial tools such as QGIS or ArcGIS to calculate the spatial extent of erosion or accretion.

Ind. 1.5: Sea water temperature

- **Definition:** Warming of water bodies, changes in ice cover *(Umweltbundesamt., 2011, 2024).*
  - **Own definition:** Sea water temperature / changes in sea water temperature
- **Rationale:** Rising sea water temperatures affect marine ecosystems, coastal biodiversity, and human health. They influence bathing comfort, seasonal tourism patterns, and the overall attractiveness of beach destinations, making temperature change a visible and measurable sign of climate

change. Warmer waters encourage the growth of potentially harmful bacteria, such as *Vibrio* species and algae, increasing the risk of infections, water contamination, and harmful algal blooms—further highlighting the health-related impacts of climate change on coastal areas.

- **Measurement:**
    - In °C, several times a day, in different water depths**.**
    - Ship-based measurement, drift buoys, satellites to obtain a comprehensive picture of temperature distribution (BSH, n.d.).

Ind. 1.6 Flood/ High water

- **Definition:** Accumulation and intensification of high and low water *(Umweltbundesamt., 2011, 2024).*
    - **Own definition:** Frequency and intensity of high and low water events occurring in a region.
- **Rationale:** The increased frequency and intensity of high water events reflect sea-level rise, and extreme weather impacts due to climate change. These events cause flooding, erosion, and damage to coastal infrastructure. Such disruptions threaten beach tourism, reduce the appeal and safety of coastal destinations.
- **Measurement:**
    - Number of occurrences and severity of them.

Ind. 1.7: Bathing temperature at the coast

- **Definition:** Describes the number of days per year on which water temperatures reach at least 15 °C in German coastal areas (Baltic Sea and North Sea) *(Umweltbundesamt., 2011, 2024).*
    - **Own definition:** Occurrence of warm water temperatures in coastal areas that are suitable for bathing activities
    - **Workshop Warnemünde:** Temperature at a depth of 1 m near the beach at a fixed location
- **Rationale:** The number of days with water temperatures suitable for bathing directly influences the length and quality of the beach tourism season. Warmer coastal waters increase visitor satisfaction and tourism demand but may also affect marine ecosystems and water quality.

- **Measurement:**
  - Annual number of "bathing days", defined as the number of days per year on which the daily mean coastal water temperature at 0.5 meter depth reaches or exceeds 15 °C at representative monitoring locations along the Baltic Sea *(Umweltbundesamt., 2024).*

Ind. 1.8: Average precipitation

- **Definition:** Seasonal mean precipitation for a given coordinate/location and change with climatic normal. Seasons are defined as Winter: December, January, February; Spring: March, April, May; Summer: June, July, August; Autumn: September, October, and November… *(Eco-union et al., 2021).*
  - **Own definition:** Typical precipitation levels for a region during each season.
- **Rationale:** Changes in average precipitation reflect shifting climate patterns that can affect beach quality, runoff, and water-related activities. Increased rainfall may reduce beach days, while droughts can stress local ecosystems—both influencing tourist satisfaction and visitation.
- **Measurement:**
  - Mean precipitation measured in millimetres (mm) or liters per square meter (L/m²) over a defined period *(Deutscher Wetterdienst n.d.-a)*.
  - *Frequency of days with precipitation that exceed the average.*

Ind. 1.9 Perceived temperature

- **Definition:** Apparent temperature. What the temperature feels like to the human body when relative humidity is combined with the air temperature *(Agulles et al., 2022).*
  - **Own definition:** Perceived temperature experienced by the human body, taking into account environmental factors such as humidity, wind, and other conditions
  - **Workshop Warnemünde:** Air temperature perceived by the human body on the beach.
- **Rationale:** Perceived temperature reflects how hot or cold conditions actually feel to beach visitors, combining heat, humidity, and wind effects. Changes in this indicator affect visitor comfort, health risks, and the overall attractiveness of beach tourism under climate change.
- **Measurement:**

- **Heat-Index:** also known as the temperature-humidity index (T-H index), describes the combined influence of temperature and humidity on physical well-being (*Climate Service Center Germany, n.d.).*
- The **universal thermal climate index (UTCI)** describes the synergistic heat exchanges between the thermal environment and the human body. There are four variables required to calculate the UTCI *(European Environment Agency, n.d.):*
  - air temperature, relative humidity), wind speed at 10m above ground level and mean radiant temperature (MRT).

UTCI Value (°C)	Thermal Stress Level
> +46	Extreme heat stress
+38 to +46	Very strong heat stress
+32 to +38	Strong heat stress
+26 to +32	Moderate heat stress
+9 to +26	No thermal stress (thermally comfortable)
+0 to +9	Slight cold stress
-13 to 0	Moderate cold stress
-27 to -13	Strong cold stress
-40 to -27	Very strong cold stress
< -40	Extreme cold stress

- **Note:** This indicator was assessed and discussed, however the perceived temperature is very individual, and we need more like an easy assessable indicator like temperature.

Ind. 1.10: Loss of biodiversity

- **Definition:** Status and trends of biodiversity and habitat loss. Main objective identified by the EU with relation to biodiversity *(THE SUSTAIN PROJECT, 2012).*
  - **Own definition:** Changes in biodiversity and destruction of habitats over time
  - **Workshop Warnemünde:** Changes in biodiversity (both increases and decreases) and destruction of habitats over time, both on land and in water.

- **Rationale:** Biodiversity loss signals ecosystem degradation caused or accelerated by climate change, affecting the natural beauty and health of coastal areas. This reduces the ecological value and attractiveness of beaches, ultimately impacting tourism and local livelihoods.
- **Measurement:**
  - Measured using indicators such as species abundance, habitat quality, and population trends for key organisms like fish, seabirds, and benthic communities (e.g. seagrass meadows). Organizations like HELCOM assess these indicators through long-term monitoring and integrated tools to determine whether ecosystems are in good environmental status *(HELCOM, 2023).*

Ind. 1.11: Invasive species

- **Definition:** Extent to which invasive fauna and flora are present within coastal and marine ecosystems *(THE SUSTAIN PROJECT, 2012).*
  - **Own definition:** Non-native plant and animal species that invade coastal and marine ecosystems and have an impact there
- **Rationale:** The spread of invasive species, often facilitated by climate change, disrupts native ecosystems and habitats. This can degrade beach environments, harm local biodiversity, and reduce the natural appeal that attracts tourists.
- **Measurement:**
  - HELCOM tracks the annual number of newly recorded non-indigenous species (NIS) to assess introduction rates.
  - Data is collected through national monitoring programs and compiled in the HELCOM core indicator and the AquaNIS (NIS=non-indigenous species) database *(HELCOM, 2023).*

Ind. 1.12: Length and width of the beach

- **Definition:** Length, width, and changes in width throughout the year of beaches with flooding risk *(Toubes et al., 2017).*
  - **Own definition:** Extent of the beach along the coastline and the width of the beach from the waterline to fixed land features

- **Rationale:** Changes in beach length and width reflect erosion and flooding impacts driven by climate change. Reduced beach size limits space for visitors and increases vulnerability of coastal infrastructure, directly affecting tourism and local economies.
- **Measurement:**
    - Length measured along the shoreline using GPS or satellite imagery (in meters or kilometers).
    - Width measured from the waterline to fixed land features (e.g., dunes, vegetation line) at regular intervals (in meters).
    - Seasonal or annual comparisons made to detect erosion, accretion, or flood-induced changes using remote sensing, aerial photos, or ground surveys *(LUNG, o. J.).*

Ind. 1.13: Coastal Erosion

- **Definition:** Evolution of the shoreline over time *(THE SUSTAIN PROJECT, 2012).*
    - **Own definition:** Changes in the coastline over time due to natural processes or human interventions
- **Rationale:** Coastal erosion reduces beach area and degrades natural coastal features. It threatens tourism infrastructure and beach accessibility, making it a visible and measurable impact of climate change on coastal tourism.
- **Measurement:**
    - Shoreline position recorded using GPS, aerial photographs, or satellite imagery at regular intervals (e.g., annually).
    - Comparison of historical and current shoreline data to calculate rates of erosion or accretion (meters per year).
    - Use of coastal profile surveys and GIS mapping to quantify changes in coastline shape and extent over time.

Ind. 1.14: Time recovery

- **Definition:** Time needed to recover to a functional operation after coastal flood events *(Toubes et al., 2017).*
    - **Own definition:** Time required to restore normal processes and conditions along the coast after a flood event.
    - **Workshop Germany:** Time required to restore normal processes (according to a regularly measured period) and conditions after a coastal flood event.
- **Rationale:** The recovery time after coastal floods measures resilience of beaches and infrastructure to climate impacts. Longer recovery disrupts tourism, reduces visitor confidence, and increases economic losses, highlighting vulnerability to climate change.
- **Measurement**:
    - Number of days or months needed for the coastal ecosystem and infrastructure to return to pre-flood conditions.
    - Measured by regular monitoring of physical, ecological, and operational indicators before and after flood events.
    - Duration varies depending on flood severity and ecosystem components affected.

Ind. 1.15: Sand temperature (New indicator)

- **Definition:** Measured temperature of the beach sand at a depth of 0cm at 12:00 and 15:00, daily during the bathing season.
- **Rationale:** Sand temperature influences visitor comfort and ecosystem health on the beach. Rising sand temperatures due to climate change can reduce beach usability during hot periods and affect species that rely on the sand, impacting tourism and biodiversity.
- **Measurement:**
    - Measured by °C at surface.
- **Notes:** This indicator is not yet monitored as routinely or systematically as air and water temperatures in Europe. To ensure reliable data collection, a dedicated monitoring system should be established, and a responsible authority designated to oversee and manage this parameter.

2. Socio-economic indicators

The socio-economic indicators include the following aspects: tourism, economy, health, safety

Ind. 2.1: Vibrio (bacteria)

- **Definition:** Number of health impairments due to the proliferation of microorganisms and protozoa caused by higher water temperatures and the decreasing bactericidal effect of UV light in the case of water turbidity due to increased algae growth caused by temperature and nutrients *(Umweltbundesamt., 2011, 2024).*
  - **Own definition:** Vibrio, a type of bacteria that thrives in warmer water and can cause infections and/or diseases in humans, especially in the elderly and individuals with pre-existing conditions.
- **Rationale:** Vibrio bacteria thrive in warming coastal waters and can cause serious infections in humans, particularly among the elderly and those with pre-existing health conditions. Their growing presence is closely linked to rising sea temperatures (especially when the water gets warmer than 20°C and represents a clear, climate-related health risk in coastal and beach environments.
- **Measurement:**
  - Water samples
  - CFU/ l *(CFU = Colony Forming Units, a measure of viable bacteria per 100 milliliters of water) (German Federal Institute for Risk Assessment, 2022).*
  - Cases of infection with vibrio bacteria have to be reported (in Germany).
- **Notes:** New sampling methods need to be developed or further refined for this purpose. Currently, there are only limited data series available from the past decades, which presents a challenge for long-term analysis and comparison.

Ind. 2.2: UV-Radiation

- **Definition:** Increased incidence of UV-related health damage (due to higher exposure as a result of low ozone events, increased hours of sunshine and climate heating) *(Umweltbundesamt., 2011, 2024).*
  - **Own definition:** Impacts of radiation from the sun that can cause skin damage.
  - **Workshop Germany:** Radiation from the sun, which is harmful to health.

    - **Workshop Saulkrasti:** Deaths due to extreme temperatures, particularly in the elderly, children, and individuals with pre-existing conditions + direct affect from sun and temperature on people and their comfort.
- **Rationale:** Increased UV radiation due to climate change raises health risks like skin damage and heat-related illnesses. This affects visitor safety and comfort at beaches, potentially reducing tourism appeal and increasing healthcare needs.
- **Measurement:**
    - UV-Index – is defined uniformly internationally. It describes the expected daily peak value of sunburn causing UV-radiation at ground level. The information is easy to obtain. The UV-Index is a guide to answering the question what sun protection measures should be taken and when *(Bundesamt für Strahlenschutz, o. J.).*

UV Index	Risk Level	Recommended Protection Measures
0–2	Low to none	Not required
3–5	Moderate	Protection recommended
6–7	High	Protection required
8–10	Very high	Protection strongly necessary
11+	Extreme	Protection is essential

Ind. 2.3: Cyanobacteria (blue-green algae)

- **Definition:** Health impairments due to increased occurrence of potentially toxic cyanobacteria (blue-green algae) *(Umweltbundesamt., 2011, 2024).*
    - **Own definition:** Occurrence of potentially harmful/toxic cyanobacteria (blue-green algae) in the water**.**

- **Rationale:** Warmer temperatures and climate change increase the growth of potentially toxic cyanobacteria in water. This poses health risks like skin irritation and poisoning, reducing water safety and visitor enjoyment, which can negatively impact tourism.
- **Measurement:**
    - Water samples, usually measures the concentration mg/m³
    - Satellite pictures of algae mats

Cyanobacteria Cell Count (cells/mL)	Chlorophyll-a (µg/L)	Health Risk Level	Recommended Action
≲ 20,000	≲ 10	Low probability of adverse effects (minor symptoms)	Post advisory signs; inform authorities
~100,000	~50	Moderate probability of irritation or illness	Watch for scums, further investigate hazard, alert
Visible scum or mat	n/a	High probability of acute poisoning or illness	Immediate measures: prohibit swimming, public alerts

Source: U.S. Environmental Protection Agency, 2025.

Ind. 2.4: Quality of bathing water

- **Definition:** Proportion of total coastal bathing waters classified as "poor quality", "sufficient quality", "good quality", excellent quality" *(THE SUSTAIN PROJECT, 2012).*
    - **Own definition:** Overall condition of coastal bathing waters intended for recreational swimming, based on cleanliness and safety (absence of bacteria, pollutants, and other health risks).
    - **Workshop Germany:** General condition of coastal waters intended for bathing, based on cleanliness & safety. Absence of potentially harmful/toxic bacteria, pollutants and other health risks (indicators summarized: bathing water quality, cyanobacteria, vibrio).

- **Workshop Saulkrasti:** Overall condition of coastal bathing waters intended for recreational swimming, based on cleanliness and safety

- **Rationale:** Warmer temperatures and changing climate conditions can increase algae blooms and harmful bacteria in coastal waters. Declining water quality threatens swimmer health and reduces the attractiveness of beaches for tourism.
- **Measurement:**
  - Regular monitoring of water parameters such as pH, water temperature, and visibility.
  - Testing for microbiological indicators including E. coli, intestinal enterococci, and Vibrio bacteria to assess contamination and health risks.
  - Measurement of toxins from harmful algae (µg/l) *(European Environment Agency, 2025).*
- **Notes:** In the workshops, stakeholders agreed to combine bathing water quality, including the presence of vibrios and cyanobacteria, into a single, comprehensive indicator. This approach simplifies monitoring and communication by consolidating three related aspects into one unified measure.

Ind. 2.5: Tourism density

- **Definition:** Intensity of beach use (people/meter of accessible beach) *(European Commission, 2006).*
  - **Own definition:** Number of visitors at the beach.
  - **Workshop Germany:** Intensity of visitors to the beach (incl. day visitors, overnight stays and residents).
  - **Workshop Saulkrasti:** Climate change caused stress in tourism, increase of services and development of infrastructure.
- **Rationale:** Changes in tourism density reflect how climate change affects visitor patterns and beach capacity. Overcrowding can strain infrastructure and ecosystems, while declines may signal reduced attractiveness due to climate impacts.
- **Measurement**:
  - Visitor counts per meter of beach measured through surveys, ticket sales, or automated counters (per day, month, or year).
  - Estimated from satellite or aerial imagery by detecting crowd sizes.
  - Derived from aggregated mobile phone location data to track visitor numbers and patterns.
  - Sensor data at beach access points.

- **Notes:** Germany says: Number of visitors/ visitor volume

To assess and monitor coastal and tourism-related indicators, Baltic Sea coastal states rely on a combination of national institutions and regional/international data platforms. These sources provide essential data on environmental, hydrological, meteorological, and biological parameters:

National Institutions by Country:

- Germany: German Weather Service (DWD), Federal Maritime and Hydrographic Agency (BSH)
- Denmark: Danish Meteorological Institute (DMI) – www.dmi.dk
- Sweden: Swedish Meteorological and Hydrological Institute (SMHI) – www.smhi.se
- Finland: Finnish Meteorological Institute (FMI) – en.ilmatieteenlaitos.fi
- Estonia: Estonian Weather Service – www.ilmateenistus.ee
- Latvia: Latvian Environment, Geology and Meteorology Centre (LVĢMC) – www.meteo.lv
- Lithuania: Lithuanian Hydrometeorological Service – www.meteo.lt
- Poland: Institute of Meteorology and Water Management (IMGW) – www.imgw.pl

Regional and International Platforms (Baltic Sea Focus):

- Copernicus Marine Environment Monitoring Service (CMEMS) – Real-time and historical marine data including sea level and storm surge indicators for the Baltic Sea → marine.copernicus.eu
- Baltic Sea Hydrographic Commission (BSHC) – Coordinates hydrographic data sharing among Baltic Sea countries → bshc.pro
- HELCOM (Baltic Marine Environment Protection Commission) – Provides regional environmental assessments, monitoring data, and climate change impact indicators → www.helcom.fi
- HELCOM Biodiversity Database – Hosts biodiversity data from various institutions across the Baltic region → maps.helcom.fi/website/biodiversity
- HELCOM Cyanobacterial Blooms Indicator – Provides data on bacterial blooms across the Baltic Sea → indicators.helcom.fi/indicator/cyanobacterial-blooms
- SeaDataNet / EMODnet (European Marine Observation and Data Network) – Offers European datasets on sea level, tides, and climate-related marine parameters → www.emodnet.eu/www.seadatanet.org

- NOAA Baltic Sea Regional Data Portals – Open-access oceanographic and climate data from international cooperation (e.g., sea level trends, satellite altimetry) → tidesandcurrents.noaa.gov

These sources support harmonized monitoring and provide crucial datasets for evaluating climate impacts, biodiversity loss, tourism pressure, and water quality across the Baltic Sea region.

During the German workshop, stakeholders from the tourism sector initially identified *drinking water quality* as a potentially relevant indicator. However, they ultimately assessed it as less directly connected to the beach environment and therefore considered of lower immediate relevance. Nonetheless, its importance could increase in the future—particularly if climate adaptation measures, such as the installation of public drinking water dispensers, are implemented.

Tropical and *torrid nights* were also discussed during the workshops and expert assessments. While stakeholders acknowledged their partial relevance, they agreed that general temperature is a more effective indicator. It is easier to understand, measure, and communicate, making it more suitable for practical use. Although tropical and torrid nights may be significant in some regions, such as the Mediterranean, they are less relevant for the Baltic Sea Region. Therefore, using temperature as a key indicator is considered more appropriate in this context.

The indicator of *heat deaths* was considered as well. However, participants ultimately recommended focusing on temperature and solar radiation as indicators instead, as these provide clear, direct, and broadly applicable information that can also inform public health and safety measures. In contrast, accurately assessing heat-related deaths is challenging, as it is often difficult to determine whether heat was the primary cause or if another underlying issue contributed to the fatality.

The selected indicators cover both physical and socio-economic aspects of climate change impacts. The proposed indicators are intended not only to convey information but also to function as practical tools that support evidence-based decision-making by local authorities, tourism managers, and planners in addressing climate change impacts on Baltic Sea beaches.

Recommendations/Findings

Based on the literature review, expert assessments, and workshops on the “climate-smart” indicators for Baltic Sea beaches, the following recommendations and findings are proposed to enhance their practical relevance and promote their integration into coastal management and climate adaptation strategies.

1. **Test indicators in practice**
    - Pilot the indicators with municipalities in Germany, Denmark, Latvia, and other interested coastal areas to evaluate their usability in real-world beach management and climate adaptation.
    - Gather feedback to improve indicator definitions, data sources, and thresholds.

2. **Simple and usable indicators**
    - Use clear, practical, and easily measurable indicators – especially for local authorities who may have limited technical resources.
    - More complex measurements (e.g. defining thresholds) should be developed and maintained at the state or national level.
    - Clearly defined metrics and thresholds not only facilitate the monitoring of climate impacts but also support the development and implementation of effective adaptation strategies.
    - There are already established indicators—such as UV radiation levels, bathing water temperature, and the frequency or intensity of storm surges – these can be used immediately without additional development.
    - More complex indicators, such as those reflecting biodiversity loss or ecological recovery times, require further coordination to define standardized measurement parameters and methodologies. These types of indicators often involve long-term observations and interdisciplinary cooperation.

3. **Integrate indicators into local planning**
    - Encourage municipalities to embed the indicators into beach management, climate adaptation strategies, and tourism planning.
    - Their implementation allows for a systematic assessment of the current situation (status quo) and helps identify areas in need of action.
    - Use them to identify priorities like shading infrastructure or erosion control.
    - Define operational thresholds (e.g., for UV radiation or sand temperatures) that trigger warnings, safety measures, or adaptive design changes.

4. **Promote Communication and Awareness**
   - Use the indicators and their results to raise awareness among residents and tourists about the impacts of climate change.
   - Present data through visual aids, dashboards, and other accessible formats to make complex information easier to understand.
   - Share positive examples where indicators have supported effective local adaptation to inspire action and build trust.
   - Involve local stakeholders early to ensure social relevance and acceptance.

5. **Support Policy Alignment**
   - The use and implementation of indicators can help align local and regional planning efforts with broader policy frameworks, such as the EU Green Deal and national climate adaptation strategies.
   - This alignment supports more coherent planning and can strengthen the case for funding applications related to climate-resilient infrastructure and sustainable tourism.

6. **Local adaptation/account for regional differences**
   - The impacts of climate change vary across regions, requiring different types and priorities of indicators to address local vulnerabilities and conditions.
   - Allow for local customization by adapting or adding indicators based on specific regional characteristics such as beach type (e.g., sandy, rocky, urban) and the tourism profile (e.g., mass tourism, eco-tourism).
   - Enable flexible prioritization of indicators to reflect local management goals, environmental conditions, and socio-economic contexts, ensuring that monitoring and evaluation efforts are meaningful and actionable at the regional level.
   - Facilitate stakeholder engagement during the customization process to incorporate local knowledge and priorities, enhancing the relevance and acceptance of the indicators.

7. **Update indicators regularly**
   - Climate conditions are evolving. Review and update the indicator set every regularly based on new research, data, and local needs to stay relevant.

Promoting Climate Resilience through the Blue Flag by integrating climate-smart indicators

To strengthen the ability of Blue Flag beaches to cope with the impacts of climate change and to promote sustainable coastal tourism, it is recommended to integrate a set of climate-smart indicators into the programme. These indicators help to identify and monitor climate-related risks and provide a foundation for informed management decisions.

Relevant indicators could include, for example, sea-level rise, storm surges, UV radiation, biodiversity changes, or visitor density. Their systematic monitoring enables beach managers to detect vulnerabilities and trends at an early stage and to respond with targeted adaptation measures.

While such indicators are generally valuable tools for coastal municipalities and beach management, the Blue Flag offers a strong entry point: by applying for and maintaining the label, municipalities commit themselves to meeting defined criteria. This provides a practical mechanism to ensure that climate-smart indicators are not only recognized but actively implemented in beach management.

The indicators could be integrated into **Sub-Criterion 2.2: Climate Change Adaptation of the Blue Flag** framework which is currently revised and expanded, making climate resilience a visible and measurable component of sustainable coastal tourism. In this way, the Blue Flag could become both a driver and facilitator for mainstreaming climate adaptation in coastal areas.

Collaboration and Implementation

The effective use of these indicators requires close collaboration with environmental agencies, climate experts, research institutions, tourism authorities, beach managers, and local stakeholders. This multi-stakeholder approach ensures both scientific validity and local relevance, strengthening the credibility and applicability of the results. Whether integrated into existing criteria—such as risk assessments, strategies, and action plans—or introduced as a new standalone criterion, the application of this set of climate-related impact indicators will support evidence-based, measurable, and adaptive beach management. The data collected through these indicators should be continuously fed into ongoing risk assessments and periodic reviews of adaptation measures. This ensures that management decisions remain responsive to current environmental and socio-economic developments, enabling dynamic and forward-looking climate resilience planning.

The certification process requires beach managers to report regularly, ideally annually, on the status and trends of these indicators, thereby ensuring transparency, comparability, and continuous progress in adapting to climate change.

Conclusion

This report has highlighted the potential of climate-smart indicators as an essential tool for improving the climate resilience of coastal areas. Their integration into beach management supports the early identification of risks, strengthens adaptation capacities, and contributes to the long-term ecological and socio-economic stability of beach destinations.

A key finding is that the Blue Flag programme offers an effective platform to introduce and operationalize these indicators. By embedding them, for example, under Sub-Criterion 2.2: Climate Change Adaptation, coastal municipalities and beach managers applying for the label would be encouraged—and obliged—to systematically monitor climate-related vulnerabilities. This creates a strong incentive to mainstream climate adaptation into local beach management.

At the same time, it is important to stress that these indicators should not be limited to Blue Flag sites. They represent valuable tools for all coastal municipalities and stakeholders engaged in beach and coastal management. Systematic data collection, monitoring, and evaluation can provide the necessary evidence base for targeted adaptation measures, independent of certification. Since not every beach has the same exposure, resources, or capacities, it is not feasible to apply all indicators. Municipalities are therefore encouraged to focus on those indicators most relevant to their specific context, ensuring that monitoring and adaptation remain both practical and useful.

Moving forward, the active involvement of stakeholders—local authorities, tourism operators, community organizations, and environmental agencies—will be critical. Collaboration across these groups ensures that the collected data is effectively translated into practical actions and that adaptation measures are aligned with local needs and capacities. The network established during this project provides a valuable basis for continued exchange and collaboration. We aim to maintain and gradually expand this cooperation with coastal municipalities in order to further support the integration of climate change considerations into beach management. Municipalities interested in joining this process are welcome to get in touch with: EUCC-The Coastal Union Germany (team@eucc-d.de).

In conclusion, integrating climate-smart indicators into the Blue Flag framework is an important step toward institutionalizing climate adaptation in coastal tourism. However, the long-term goal must be their broader application across all coastal areas, thereby building resilience not only within certified beaches but across coastal systems more generally.

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Annex I: Results workshop I

Climate resilience on the beach:
Results of the workshop: "Understanding challenges, recognizing opportunities, acting together" on 12 April 2024

The economic development of the Baltic Sea region benefits from flourishing coastal tourism, which, however, is increasingly impacted by climate change. Rising sea levels, coastal erosion, and more frequent extreme weather events are jeopardizing the use of beaches. The consequences can be reduced attractiveness, landscape degradation, and increased health risks.

methodology

The extent to which Baltic Sea beaches are specifically affected and impacted by climate change was explored during the first workshop. The 18 participants from the tourism industry, administration, and science examined the impacts of climate change and the resulting opportunities and risks, and discussed initial adaptation measures.

Results

Impact on the beach

- Increase in weather extremes
- Sea level rise (beach narrower)
- Increase in bacteria, jellyfish, algae
- Declining water quality
- Rising water and air temperatures
- More sun/sun hours
- Coastal erosion
- Loss of infrastructure

Opportunities

- Season extension (no more tourists in summer)
- More visitors all year round
- internationalization
- Promote additional/alternative tourist offers

Risks

- Unpredictability
- Weather extremes (especially in autumn)
- More tourists
- More garbage, traffic, hotels, infrastructure
- Less ecosystem recovery and higher pollutant input

Adaptation measures

- Increase measurements/monitoring (e.g. (bathing) water quality
- More trash cans and sanitary facilities
- water dispenser
- Shady spots/shading
- Sand and stone embankments to prevent land erosion
- Limiting the number of visitors
- Adjustment of nationwide holiday periods
- Creating more attractive working conditions
- Multilingualism (information, advertising, personnel)
- Alternative ("Indoor") offers/alternatives for the beach
- Educational offerings

Cooperation with relevant and affected stakeholders

- Research institutions & science
- Authorities (Office for Environment & Climate Protection, Health Authorities, Coastal Protection Authorities, StaLU MV)
- Politics and local politicians
- Municipalities & Administration
- Tourism industry (hotels, beach operators, restaurants)
- Residents (tourism acceptance)
- Guests/beach users (swimmers, sunbathers, anglers)
- Non-governmental organization

Conclusion

- Changes are primarily perceived negatively
- **Sea level rise, extreme weather events, deterioration of (bathing) water quality are the three most critically seen changes**
- **More cooperation (also across borders) is required**
- **Season extension has positive & negative effects**
- **The tourism sector should develop an adaptation strategy**

The BEACH-SOS project supports coastal communities in adapting to climate change and is co-financed by the Interreg Baltic Sea Programme 2021-2027.

Annex II: Results workshop II

Climate resilience on the beach
Results of Workshop II: "Understanding challenges, recognizing opportunities, acting together" on 11 March 2025

Coastal tourism in the Baltic Sea region is increasingly affected by climate change. Rising sea levels, coastal erosion, and extreme weather threaten the stability and attractiveness of beaches. To capture these developments, a practical set of indicators is being developed. It will support beach managers in monitoring changes, analyzing trends, and planning targeted adaptation measures.

Methodology

In a three-stage evaluation process, 15 experts from science, tourism, administration and NGOs evaluated a selection of physical and socio-economic indicators according to criteria such as relevance, measurability and applicability.

Results

Indicator	Relevance	Measurability
UV-Radiation	↑↑	Established methods (e.g., UV index), directly measurable and applicable, easily communicated
Bathing Water Quality	↑↑	Established methods, directly measurable and applicable, vibrio analysis possibly costly
Storm Surge	↑↑	Established methods, data collected by authorities, economically feasible, directly applicable
Bathing Water Temperature	↑↑	Easily measurable with little effort (e.g., automatic loggers), high data availability, fixed locations
Sand Temperature	↑	Easily measurable, directly usable, well communicable
Drinking Water Quality/Amount	↑	Established methods, measured by water providers, no direct beach connection
Perceived Temperature	↑	Realistic depiction using combined weather data, but influenced by subjectivity and higher effort
Recovery Time	↑	High survey effort, long-term data needed, experts required, limited short-term applicability
Visitor Numbers	→	Measurable via e.g., spa taxes, staff-intensive
Biodiversity Loss	→	High data collection effort, long-term data, experts required, limited short-term usability
Beach Area Loss	→	Costly and complex surveys needed (e.g., laser scans of coastal processes)

Conclusion

- Practical and easily measurable indicators are essential for assessing the impacts of climate change on Baltic Sea beaches.
- Municipalities need simple, directly usable indicators; more complex data collection and the definition of threshold values should take place at the state or federal level.
- Clear metrics and thresholds provide guidance and support adaptation strategies.
- Combining large-scale and locally differentiated data increases the significance of the results.
- Already established indicators such as UV radiation, bathing water temperature, or storm surges can be used directly.
- More complex indicators, such as biodiversity loss or recovery time, require further coordination for the definition of measurement parameters.
- The selected indicators cover both physical and socio-economic aspects; they are being tested at pilot beaches

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