



D5.3 Safe Operating Space visualization tool - FINAL

SOS-Water deliverable report**D5.3 - Safe Operating Space visualization tool**

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Publishable Executive Summary

This deliverable presents the Safe Operating Space (SOS) visualization tool, developed within the framework of Task 5.2 (Analysis and synthesis of SOS) of the SOS-Water project. Building directly on the final evaluation results of D5.2, the tool provides an intuitive interface for exploring multi-dimensional SOS assessments across case studies.

The tool translates the project’s complex modelling and evaluation framework into a user-friendly platform for exploring case study results. It enables spatial and aggregated visualization of indicators and scenarios, helping stakeholders, researchers, and policy makers to interpret system vulnerabilities and potential adaptation pathways.

A central feature is the SOS radial chart, which aggregates indicators by water function and provides a conservative assessment of system safety. The chart reacts instantly to user selections and can be exported for use in reports, workshops, and policy briefs. The application is built entirely on open-source technologies, ensuring accessibility, transparency, and sustainability beyond the lifetime of the project.

The visualization tool can be found at this link <https://sos-water-dashboard.iiasa.ac.at/>.



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Description of deliverable

1. Introduction

The visualization tool addresses a key challenge identified in earlier project phases: the need to communicate multi-dimensional Safe Operating Space results in an intuitive and accessible way. Deliverable D5.2 provided the final evaluation of the SOS framework, including a common structure of indicators and thresholds that were aggregated into five water functions: supply, carrier, state, productive, and regulatory. These indicators were applied across four case studies—Danube, Rhine, Júcar, and Mekong—for both a historical reference period (1970–2010) and three future time horizons (2030–2070), represented by distinct socio-economic and climate scenarios: SSP1-2.6 (sustainable pathways), SSP3-7.0 (regional rivalry), and SSP5-8.5 (fossil fuel-driven development). The resulting assessment revealed several instances where thresholds were transgressed under both current and future conditions. The analysis produced a set of multi-dimensional results, showing both safe and unsafe spaces depending on the socio-economic and climate scenarios considered.

D5.3 translates these results into a harmonized and interactive visualization platform. The tool provides a common visualization standard across case studies, ensuring comparability and transparency. Designed to serve both expert users and non-technical stakeholders, the tool promotes inclusive communication and decision support. It also establishes the technical baseline for integrating future work on management pathways (D5.5) and uncertainty analysis (D5.4).

1.1. Key Features

The core functionality of the application lies in its ability to spatially visualize key indicators derived from the four SOS-Water case studies—Danube, Rhine, Mekong, and Júcar—together with their thresholds, in order to show where water systems remain within or exceed the safe operating space. Figure 1 and 2 shows the evaluation of one of the indicators for the Danube basin (Magnitude of Monthly Flow Alteration for dried years, Mmfa-Dry, see D5.2 for more information). Colors indicate for each subbasin whether the indicator is below its threshold safe (towards green) and over (towards red).

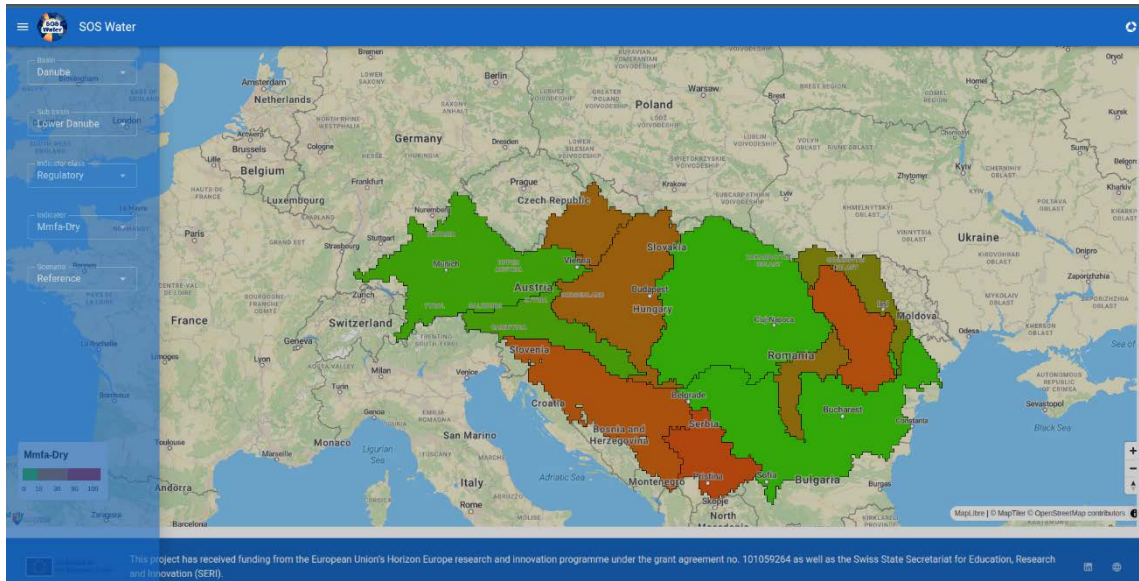


Figure 1. Example of the visualization tool for one of the indicators (Mmfa-Dry) of the Danube basin case study for the historical reference period. The basin is divided into 11 major subbasin utilized for the indicators evaluation (see D5.2 for more information). Color scale represent how the indicator value performs according to its threshold. Users can select using the menu on the left which basin and subbasin to visualize, which function, indicator and scenario.

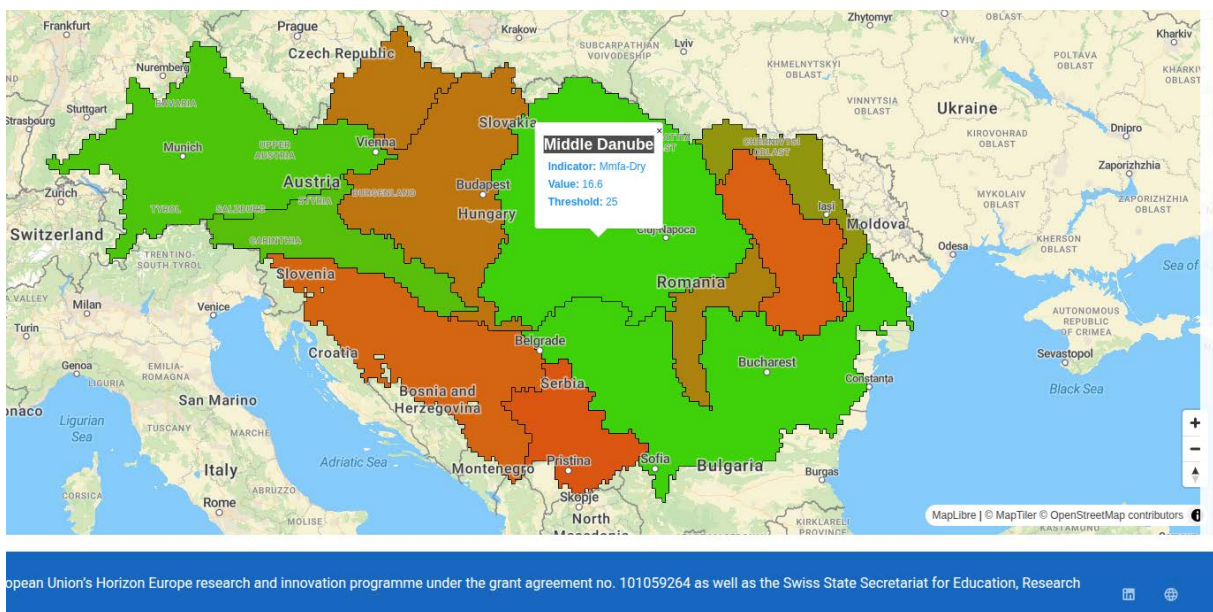


Figure 2. Example of the visualization tool displaying the indicator Mmfa-Dry for the Danube basin case study for the historical reference period. The interface allows users to examine indicator values in each sub-basin in relation to their corresponding thresholds. In this example, the pop-up window illustrates the results for the Middle Danube sub-basin, showing both the computed indicator value and its threshold for direct comparison.

These indicators are accompanied by clear and concise explanations regarding their meaning and how they are calculated, which ensures that users can interpret their meaning and significance correctly (see Figure 3). For enhanced clarity and context, the indicators are organized according to the five water functions defined in D5.2, namely supply, carrier, state, productive, and regulatory functions. This

grouping provides a logical structure that helps users analyze the performance of water-related systems and processes in a systematic manner (Figure 3).

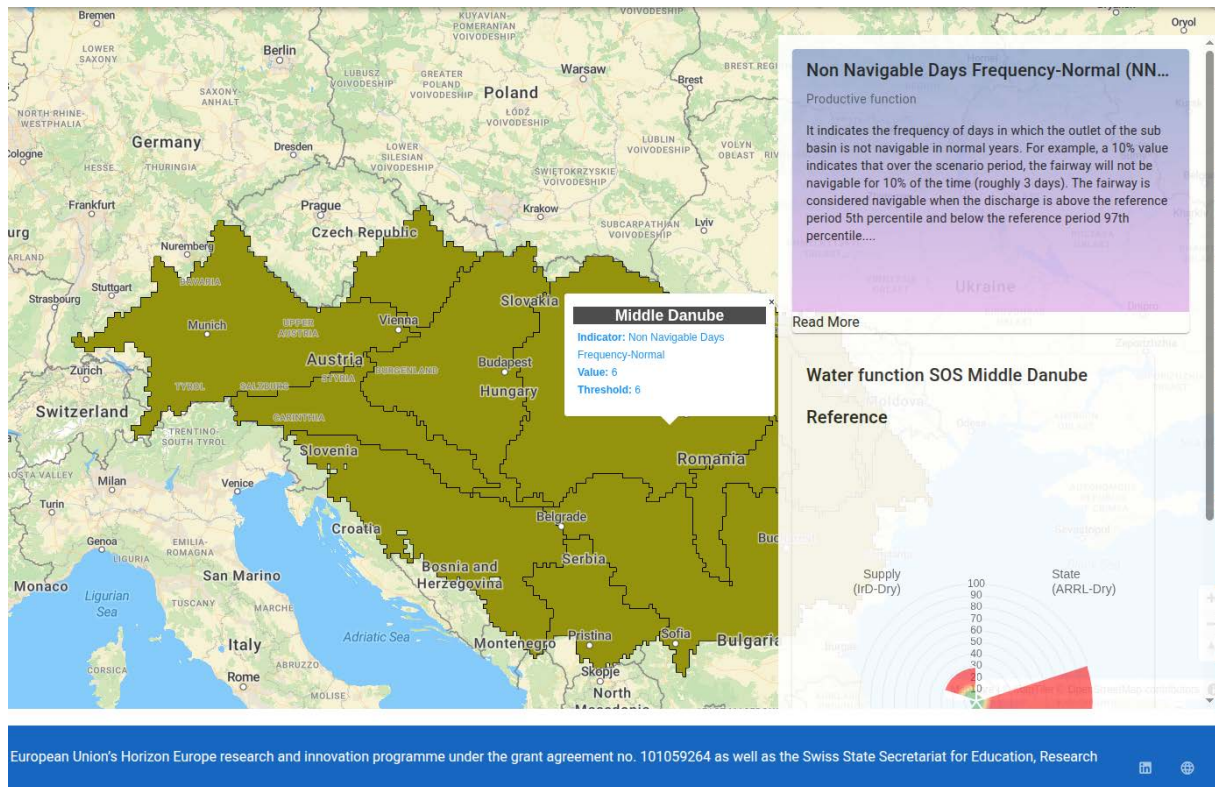


Figure 3. Example of the visualization tool showing the indicator frequency of non-navigable days for normal years (see Deliverable D5.2 for details) in the Danube Basin case study for the historical reference period. Additional information on the indicator type, its calculation, and the underlying function is also provided.

A central feature of the tool is the radial SOS-Water chart, which provides a holistic overview of the safe operating space for a specific case study and scenario (Figure 4). The chart reacts instantly to the user's spatial selections and dynamically displays the aggregated values of the indicators. In the current version, the SOS is defined by the same water functions as the indicators, with each function's score calculated using the value of the worst performing among its indicators. This approach delivers a conservative and robust assessment of system performance in relation to the safe operating boundaries.

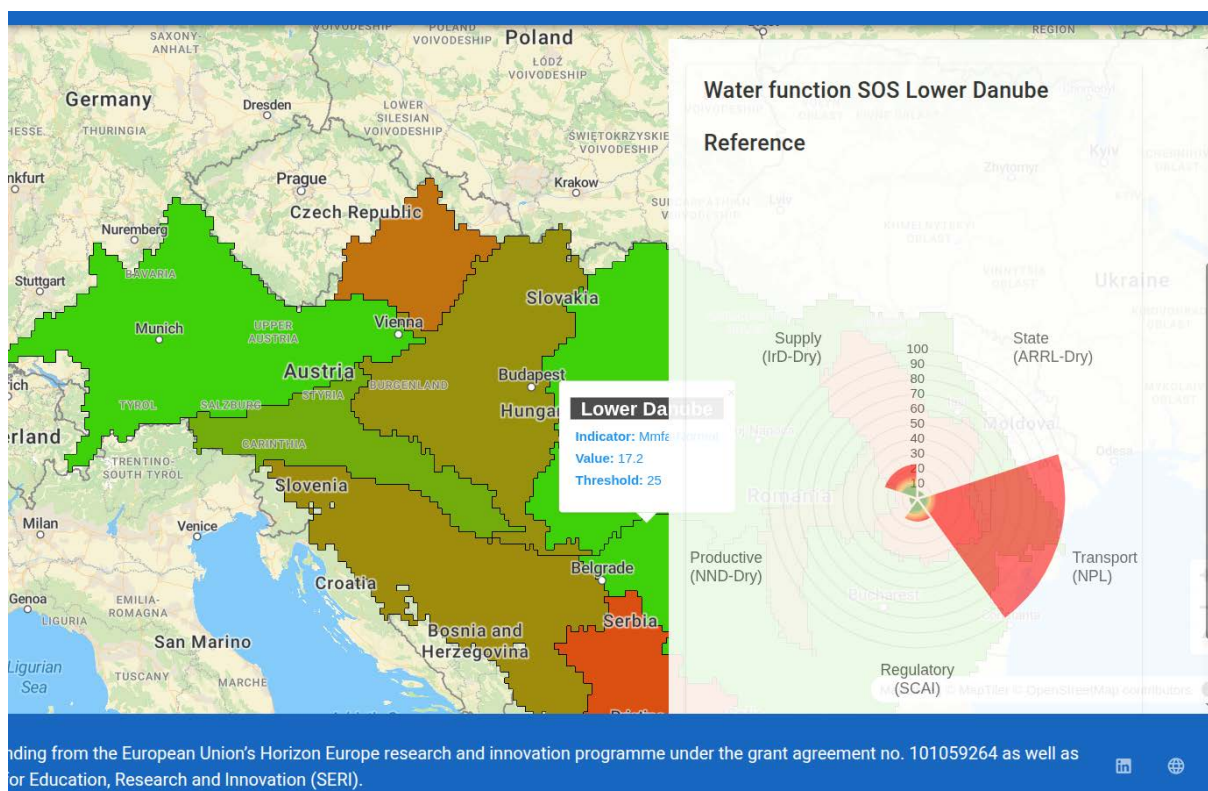


Figure 4. Radial chart of the SOS-Water assessment for the Lower Danube sub-basin in the historical reference period. Each of the five water functions is represented by the score of its lowest-performing indicator. The color scale, ranging from green (safe) to red (unsafe), reflects whether the function remains within or exceeds its threshold. The size of each function segment indicates the extent to which the threshold is transgressed.

For practical use in reporting and communication, all charts and maps generated by the tool can be exported as PNG and integrated into project deliverables, stakeholder workshops, and policy briefs.

1.2. Technology Stack

The application has been developed using a completely open-source technology stack to ensure sustainability and long-term use. The backend is a robust Python-Flask application responsible for storing and retrieving data from a SQL database, ensuring efficient data management. The user-friendly frontend is built with Javascript React, providing a smooth and responsive user experience. This combination of freely available, open-source technologies makes the application a transparent, adaptable, and cost-effective solution. Frontend and backend are containerized in Docker images and deployed on a Kubernetes infrastructure. Figure 5 illustrates the overall structure of the application, highlighting the backend and frontend components of the stack.

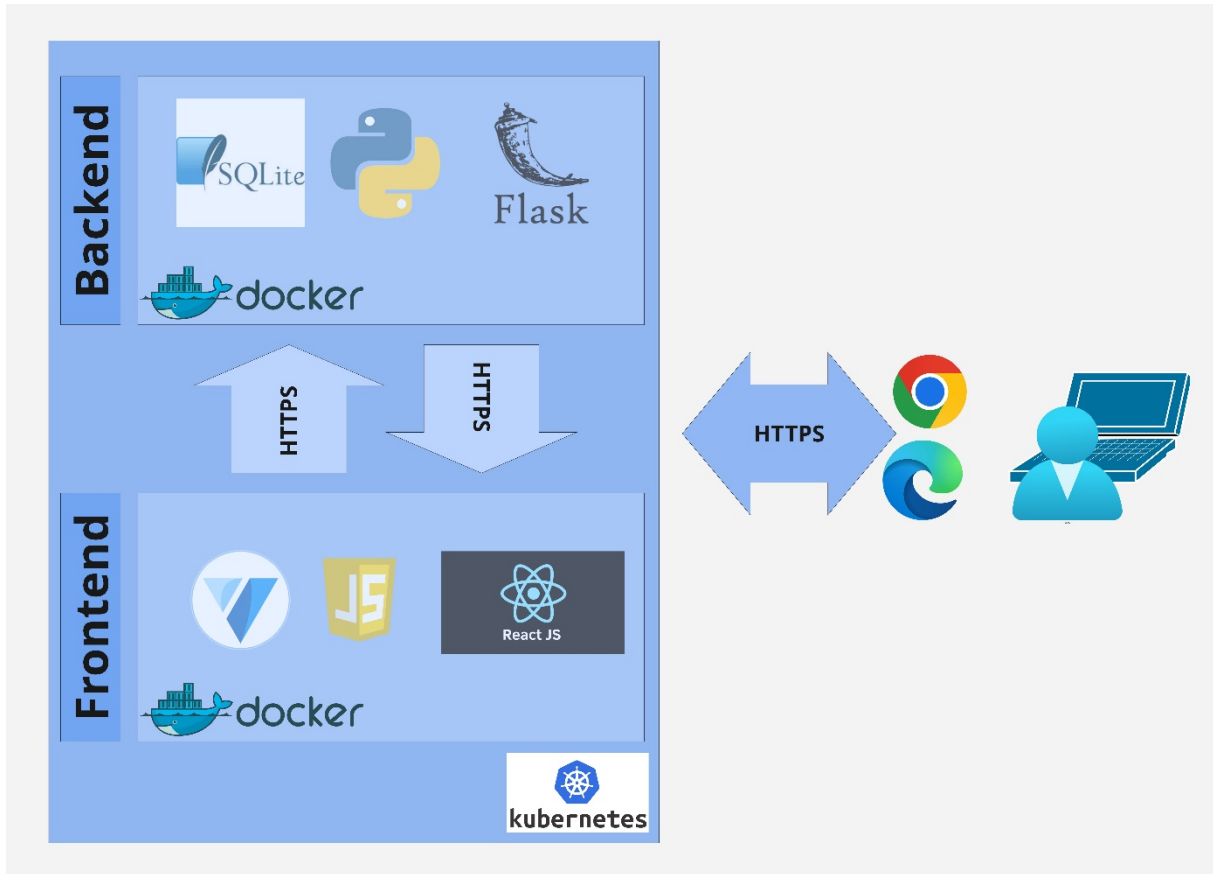


Figure 5. Technology stack of the developed visualization tool, showing the main backend and frontend components.



Conclusions

The Safe Operating Space visualization tool ensures that the multi-dimensional results from D5.2 are accessible, comparable, and usable. It contributes to WP5 by transforming the analytical outcomes of the evaluation into an interactive knowledge product. It reinforces WP1 by linking with stakeholder-defined pathways, WP2 by drawing on the outputs of the integrated modelling system, and WP4 by making the indicators and thresholds visible and policy relevant. In addition, it directly supports dissemination activities under WP6, serving as one of the project's flagship outputs for stakeholder workshops and EU-level policy events.

By aligning fully with the methodological framework of D5.2, the tool guarantees consistency across case studies and provides a coherent representation of system performance in relation to safe operating boundaries. It also provides the baseline for integrating the work on management pathways and uncertainty analysis in the upcoming deliverables. Beyond the project itself, it sets the stage for replication in other basins and for alignment with the European Water Resilience Strategy. In this way, it ensures that the outcomes of SOS-Water remain accessible and impactful beyond the lifetime of the project.

