RETOUCH NEXUS

Deliverable D1.3

REsilienT water gOvernance Under climate CHange within the WEFE NEXUS

List of Water Governance Indicators

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DEM	Demonstrator, pilot, prototype, plan designs	
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Dissemination Level		
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Executive summary

One of the RETOUCH NEXUS project objectives is to provide a collection of existing and new indicators for monitoring water governance building on the existing OECD water governance indicator framework. RETOUCH NEXUS aims to use the multi-level and cross-sectoral nature of the Water-Energy-Food-Ecosystems (WEFE) Nexus to propose a list of indicators that allow assessing water governance over different spatial and temporal scales. First, across temporal scales, an intervention may have impacts over the short, medium and long term. Second, across a spatial scale, an intervention may deliver downward cascading impacts from its implementation at a larger scale (top-down impacts) or upward impacts resulting from up-scaling local practices (bottom-up impacts).

We provide two perspectives for our framework: a research perspective (Figure 1) and a policy-making perspective (Figure 2). Based on the Figure 1, on a first level, indicators to assess the enabling environment and baseline conditions for good water governance are presented. The second level considers indicators and metrics that assess progress towards policy goals. The third and final level proposes indicators to monitor policy impacts and results over longer periods of time and broader scales. On the other hand, Figure 2 maps the proposed indicators to the spatial scale of the project case studies[1] and to the timeline of policy objective (short and long term). The collection of indicators proposed by RETOUCH NEXUS reflects the complexity of cross-sectoral, multi-level and multi-stakeholder water governance frameworks.

In summary, we consider the following types of indicators:

- **Existing frameworks:** Indicators within these frameworks provide a starting point for monitoring water governance systems (OECD 2018a&b and Melloni *et al.* 2022). RETOUCH NEXUS recognizes their potential and proposes directions to further complement these frameworks.
- **Determining the baseline:** A subset of indicators from the EU Water Framework Directive (WFD) - considering pressure and Key Types of Measure (KTM) indicators - is included to assess water governance at smaller scales.
- **Governance enabling environment:** Qualitative indicators to assess selected key governance areas (policy coherence, institutional settings, innovative governance and stakeholder engagement).
- **Hydrological outputs:** Hydrological model outputs – refer to as metrics - to analyse water systems at smaller scales. These metrics can also be used as inputs to calculate other indicators.
- **Specific water dimensions:** A subset of quantitative indicators to assess areas of importance for water governance, such as water scarcity, land use change, green water, soil quality, cost recovery and economic productivity.
- **Pairwise WEFE Nexus interactions:** These quantitative indicators provide the main building blocks for understandings WEFE nexus interactions accounting for cross-sectoral water allocations (resource flows) and intensities (water footprint).
- **Joint WEFE Nexus interactions:** An adapted version of the water withdrawals to availability ratio is proposed to include water allocations for energy and food taking into account environmental flow requirements.

[1] https://retouch-nexus.eu/case-studies/

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- **Composite indicators:** Composite indicators - that are fit for the assessment of water governance within the WEFE Nexus - are used to provide benchmarks and assess progress towards policy goals, especially on broader scales and longer terms.

Policy-makers and practitioners may use these indicators to monitor if (and how) specific water governance arrangements and interventions (e.g. economic instruments) deliver policy objectives.

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Figure 1 – Map of RETOUCH NEXUS indicators for assessing water governance over different spatial and temporal scales (Research Perspective).

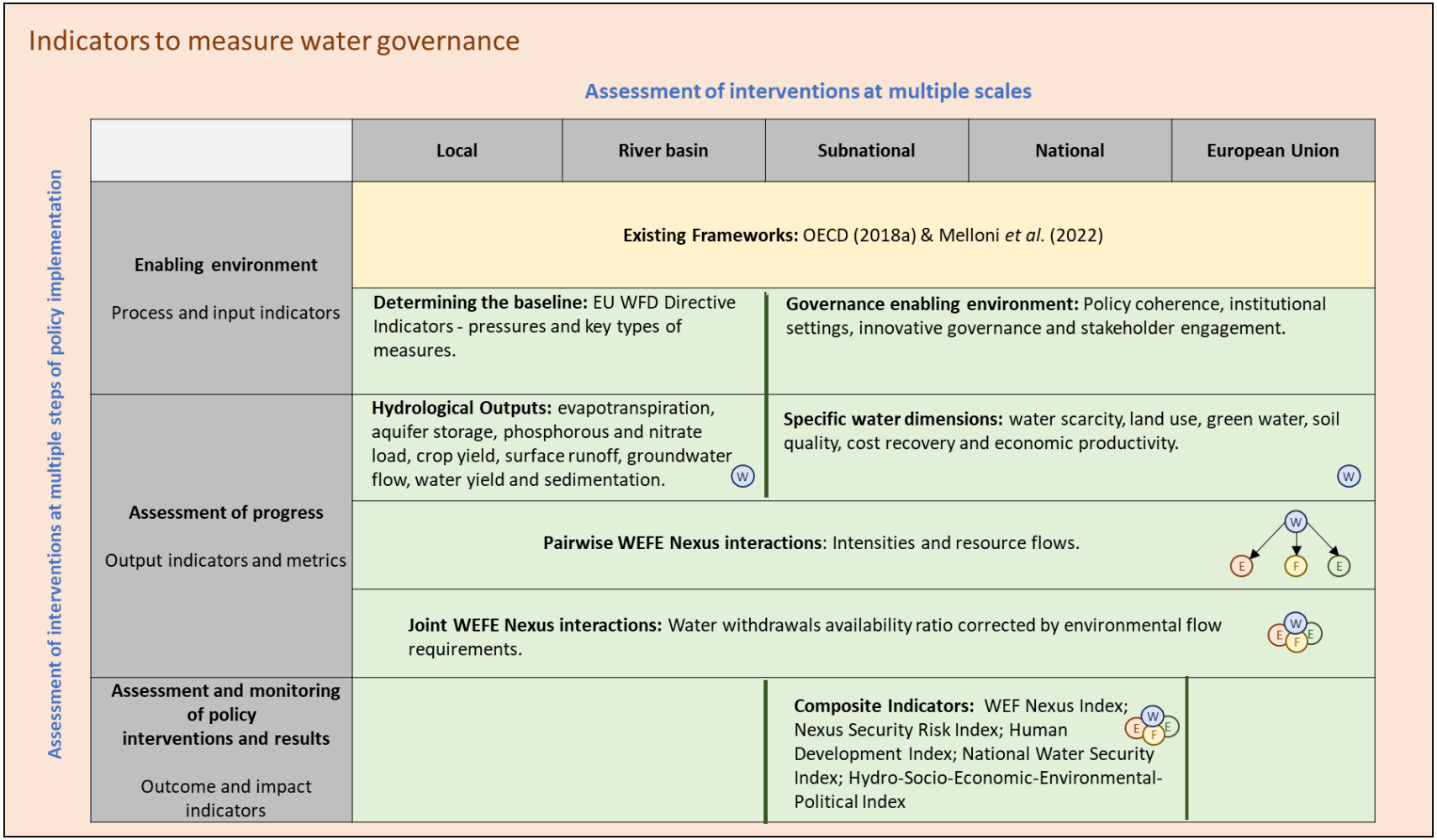

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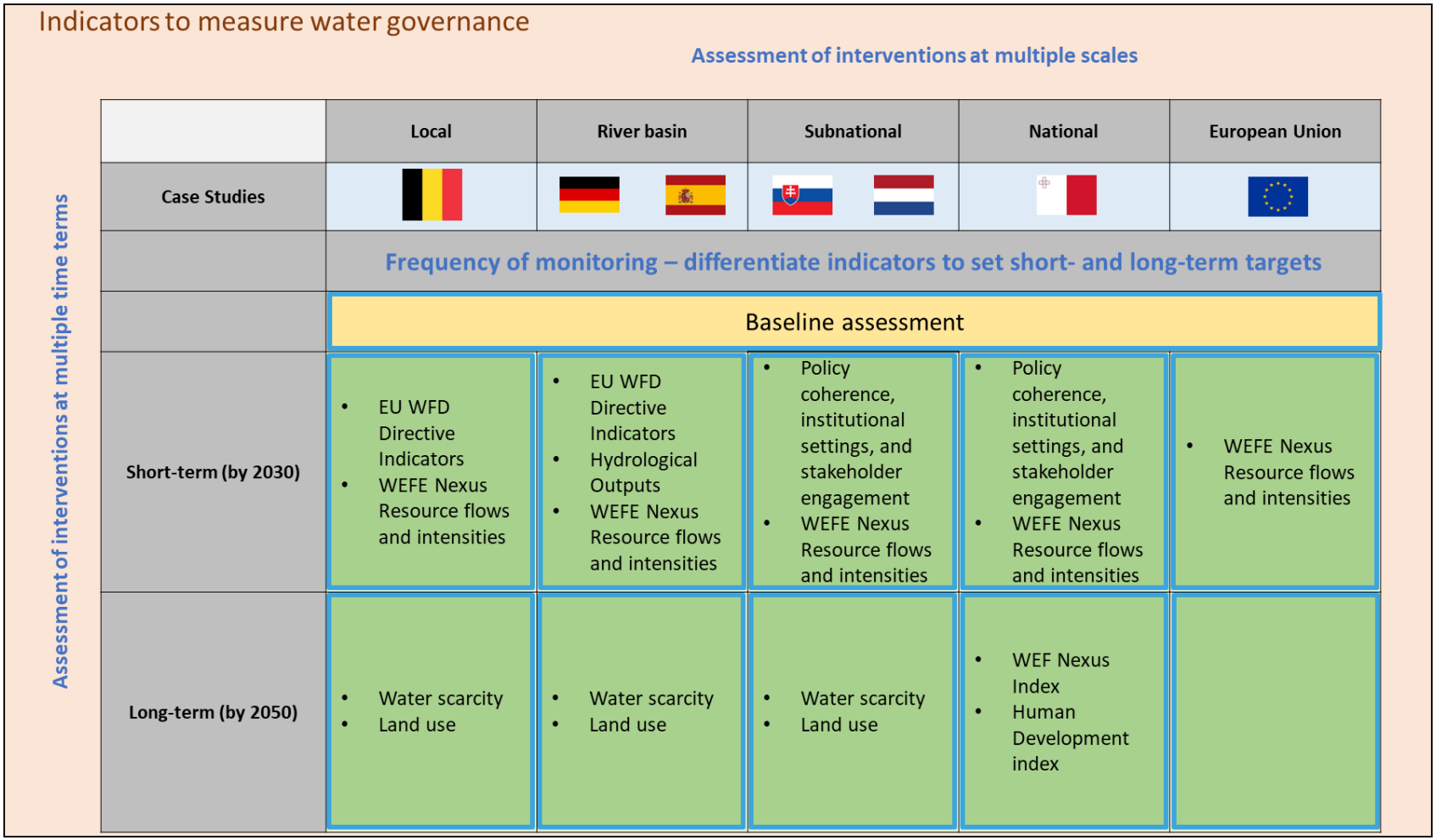
Figure 2 – Map of RETOUCH NEXUS indicators for assessing water governance over different spatial and temporal scales (Policy-making perspective).



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Abbreviations

EC	European Commission
ES	Ecosystem Services
EU	European Union
GESI	Gender Equity and Social Inclusion
HSEEPI	Hydro-Socio-Economic-Environmental-Political Index
KPIs	Key Performance Indicators
KTM	Key Types of Measure
MDWL	Matching Degree of Water Land Resources
NESRIX	Nexus Security Risk Index
OECD	Organization for Economic Co-operation and Development
PoM	Programmes of Measure
RBD	River Basin Distric
RBMP	River Basin Management Plan
SDGs	Sustainable Development Goals
SOC	Soil Organic Carbon
UDI	Human Development Index
WEF	Water, Energy, Food
WEFE	Water, Energy, Food, Ecosystems
WEI	Water Exploitation Index
WFD	Water Framework Directive
WREI	Wastewater Reuse Effectiveness Index
WSI	Water Stress Index
WTA	Water Withdrawals to Availability

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1. Introduction

The objective of this report is to provide a collection of existing and new indicators for monitoring water governance. Water governance systems aim to determine water allocation and decide who receives water-related benefits, when, and how (Jacobson *et al.*, 2013). However, determining these allocations in practice is challenging due to the multiple interactions among water and the energy, food and ecosystems sectors (Sušnik, 2022). Within this context, the Water, Energy and Food (WEF) Nexus concept originated as an approach for improved management across sectors and scales (Hoff *et al.*, 2011). RETOUCH NEXUS aims to mainstream this approach in the context of water governance.[2]

In what follows, Section 2 of this report describes the methodology for the selecting and grouping indicators. Section 3 describes the proposed indicators. Section 4 maps the indicators into a monitoring framework. Finally, Section 5 presents some conclusions and highlights further steps.

2. Methodology

This document compiles information from the existing water governance literature. We performed our search in google scholar using the keywords 'Water governance', 'WEF Nexus', 'WEFE Nexus' and 'Indicators'. We shortlisted the results to account for those that included indicators that are relevant to the objectives of the RETOUCH NEXUS project. We considered technical reports, academic articles, and policy documents. We compiled a preliminary list of indicators that was complemented with inputs from RETOUCH NEXUS project partners. Afterwards, we mapped the indicators in the monitoring frameworks described in Section 4 of this report. We refined our mapping by developing consultations with key experts and stakeholders working in water governance and policy implementation in the EU (e.g., EU REA and SIWI). The Final mapping of indicators considered the following criteria:

- Indicators should be relevant to the current policy and regulatory framework of the European Union (e.g., the Water Framework Directive, Floods Directive, Drinking Water Directive, Urban Wastewater Treatment Directive, Habitats Directive).
- Indicators should be relevant for the Sustainable Development Goals (SDGs).
- Indicators should span multiple time planning horizons (e.g., short-term, long-term).
- Indicators should be applicable to the multiple scales of the RETOUCH NEXUS case studies.[3]
- Indicators should allow setting or developing policy objectives.
- Indicators should address the multiple types of water (Green water, blue water, grey water).
- Indicators should span the different pillars of the WEFE Nexus.

3. RETOUCH NEXUS Indicators for water governance

Taking into account the methodology described above, in this section, we present the list of selected indicators for monitoring water governance. We divide these indicators in the following groups: existing frameworks, determining the baseline, governance-enabling environment, Hydrological outputs, Specific water dimensions, pairwise WEFE Nexus interactions, Joint WEFE Nexus interactions and composite indicators. In the following subsections, we describe each of these categories and

[2] A detailed description of the conceptual background proposed by the RETOUCH NEXUS project may be found on the attached RETOUCH NEXUS project concept note.

[3] Case studies | Retouch-Nexus

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highlight the connections of each indicator with the SDGs. An important remark is that we do not limit our list of indicators to the evaluation of governance settings. While we consider this type of indicators, we also include indicators and metrics that are relevant for governance in the sense that they allow measuring possible implications and outcomes of governance systems. This allows using our indicators to assess not only governance settings but also the results of policy implementation.

3.1. Existing frameworks

The current literature provides useful water governance monitoring frameworks. The most significant examples are the OECD indicator framework (OECD, 2018a) and a multi-level framework recognizing the WEF Nexus approach provided by Melloni *et al.* (2022). RETOUCH NEXUS recognizes these frameworks as a starting point. Specifically, indicators within these frameworks exhibit significant potential to assess the enabling environment for robust water governance systems. We give a detailed list of these indicators in the (RETOUCH NEXUS concept note). Indeed, RETOUCH NEXUS encourages making use of these indicators to identify the means to improve existing governance settings in any given context[4]. While recognizing their importance, the focus and contribution of the RETOUCH NEXUS project is on subsequent levels of indicators that, in addition to the assessment of the enabling environment, provide the tools to assess the results and impacts of policy interventions at different scales. We give detailed descriptions of these layers of indicators in the following sub-sections.

3.2. WFD Indicators

One critical step to formulate better policy responses is correctly identifying current baseline conditions (Ferraro, 2009). For the European Union (EU) a useful tool for this task is the Water Framework Directive (WFD) and the indicators provided within. Indeed, the WFD is the main water policy framework for the EU. Within, member states are required to deliver river basin management plans (RBMPs), develop programmes of measures (PoM)s for each river basin district (RBD) and report progress on implementing key types of measures (KTMs). Currently, a third generation of RBMPs is in progress covering the period between 2022 and 2027, and guidelines for reporting progress are available (European Commission, 2023). This guidance contains indicators to assess the main pressures for RBDs and to assess progress towards achieving selected KTMs. RETOUCH NEXUS recognizes the utility of these indicators for assessing baseline conditions at smaller scales, in particular, the river basin or local scale.
Table 1 provides a selection of these indicators.

Table 1. EU WFD pressures and KTM indicators

ID	Indicator definition	Units of measure	SDGs
1_1	Area/Length of water bodies where hydro morphological alterations **[for …]** are preventing the achievement of WFD objectives. **Sub indicators:** - Agricultural purposes. - Aquaculture purposes. - Hydropower production.	Area (KM2) / Length (KM)	

[4] Comprehensive descriptions and guidelines to apply these frameworks are available in OECD (2018a), OECD (2018b), OECD (2022) and Melloni *et al.* (2022)

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ID	Indicator definition	Units of measure	SDGs
	- Public water supply. - transport purposes.		
1_2	Area of water bodies where physical loss of habitats is preventing the achievement of objectives.	Area (KM2)	
1_3	Number of contaminated sites preventing the achievement of objectives.	Number of sites	
1_4	Number of discharges not connected to sewerage network that are preventing the achievement of objectives.	Number of sites	
1_5	Number of sites associated with **[]** preventing the achievement of objectives. **<u>Sub indicators:</u>** - Drinking water - Flood Protection - Hydropower - Industry - Irrigation - Other uses (Navigation, recreation)	Number of sites	
1_6	Area of **[]** required to be covered by measures to achieve WFD Objectives. **<u>Sub indicators:</u>** - Water bodies - Agricultural land - Forest land	Area (KM2)	
1_7	Area of **[]** where water pricing policy measures are required to achieve the objectives of WFD Article 9. **<u>Sub indicators:</u>** - Water bodies - Agricultural land - Forest land	Area (KM2)	

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ID	Indicator definition	Units of measure	SDGs
			
1_8	Length of river network requiring measures to achieve objectives.	Length (KM)	
1_9	Area/length of water bodies/river networks required to be restored or reconnected to floodplains to achieve objectives.	Area (KM2) / Length (KM)	
1_10	Number of contaminated sites to be remediated or where preventative actions need to be taken to achieve objectives.	Number of sites (Which ones?)	
1_11	Number of drinking water protection zones required to achieve objectives.	Number of Zones (Which ones?)	
1_12	Number of Farm Surveys required to achieve objectives.	Number of Surveys (Which ones?)	
1_13	Number of installations where upgrades or improvements are required to achieve objectives.	Number of Installations (Which ones?)	
1_14	Number of research studies that are required to achieve objectives.	Number of research studies (Which ones?)	

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ID	Indicator definition	Units of measure	SDGs
1_15	Number of storm overflows required to be upgraded to achieve objectives.	Number of storm overflows (Which ones?)	
1_16	Number of surface water interceptors and treatment facilities required to achieve objectives.	Number of surface water interceptors and treatment facilities (Which ones?)	
1_17	Number of waste disposal sites required to be upgraded or remediated to achieve objectives.	Number of waste disposal sites (Which ones?)	
1_18	Number of wastewater treatment works requiring to be constructed or upgraded to achieve objectives.	Number of wastewater treatment works (Which ones?)	
1_19	Reduction (%) in water consumption required to achieve objectives.	Reduction (%) in water consumption required	

Source: European Commission (2023).

3.3. Governance enabling environment

RETOUCH NEXUS considers qualitative indicators for assessing selected key governance areas: policy coherence, institutional settings, innovative governance and stakeholder engagement. The project partners have identified indicators within these dimensions. We list these indicators in Table 2. Generally, their application fits a variety of scales. Nevertheless, a starting point for its application will

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often be larger scales including the subnational and national scales. Their specific nature allows an additional level of indicators to assess the enabling environment for well-functioning water governance systems.

Table 2. Indicators for assessing governance-enabling environment.

ID	Indicator definition	Units of measure	Target governance dimension	SDGs
2_1	Do stakeholders at the […] level consider the WEFE nexus approach relevant? **Sub indicators:** - International river basin scale - National Scale - Regional scale - Local scale	Yes/No	Policy coherence	
2_2	Is there any familiarity with a WEFE nexus or other type of integrated approach in the country involved at the **[…]** level? **Sub indicators:** - International river basin scale - National Scale - Regional scale - Local scale	Yes/No	Policy coherence	
2_3	Is there any willingness to implement a WEFE nexus or other type of integrated approach in the country at the **[…]** level? **Sub indicators:** - International river basin scale - National Scale - Regional scale - Local scale	Yes/No	Policy coherence	
2_4	Is there a supportive scientific infrastructure for a WEFE nexus approach or other type of integrated approach?	Yes/No	Policy coherence	

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ID	Indicator definition	Units of measure	Target governance dimension	SDGs
2_5	Does the country have a common practice of policy evaluation?	Yes/No	Policy coherence	
2_6	Do institutional settings facilitate a multi-level approach?	Yes/No	Institutional Settings	
2_7	Do institutional settings facilitate a cross-sectoral approach?	Yes/No	Institutional Settings	
2_8	Are institutional settings regularly being revisited, evaluated and discussed?	Yes/No	Institutional Settings	
2_9	Do institutional settings reflect aspirational goals?	Yes/No	Institutional Settings	
2_10	Are innovative institutional settings being implemented at different levels?	Yes/No	Institutional Settings	
2_11	Are underlying policy paradigms being revisited, evaluated and discussed?	Yes/No	Innovative governance	
2_12	Is governance built on an overarching and challenging policy paradigm?	Yes/No	Innovative governance	
2_13	Are there experiments* with innovative governance practices in place?	Yes/No	Innovative governance	
2_14	Are governance experiments* focused on implementing new policy paradigms?	Yes/No	Innovative governance	
2_15	Are experiments* done with new practical tools?	Yes/No	Innovative governance	
2_16	Are experiments* stakeholder driven?	Yes/No	Innovative governance	
2_17	Are experiments* evaluated in a scientifically sound manner?	Yes/No	Innovative governance	
2_18	Are there cross-sectoral and inter-departmental coordination mechanism for decision making, and resolving conflicts?	Yes/No	Innovative governance	
2_19	Are there mechanisms in place for mainstreaming GESI in policies, implementation and regulation?	Yes/No	Innovative governance	
2_20	Is there equitable and balanced participation of WEFE sectors in policy and decision-making processes?	Yes/No	Innovative governance	
2_21	Is there a transparent and accessible platform for stakeholders, including responsible authorities to provide input and feedback on water laws, policies and regulations?	Yes/No	Innovative governance	
2_22	Are there formalized mechanisms for public consultation and feedback during the water law or policy development?	Yes/No	Innovative governance	
2_23	How are conflicts of interest managed and disclosed among the responsible authorities and stakeholders involved in water law and policy making?	Yes/No	Innovative governance	
2_24	To what extent are women and marginalised populations consulted during policy or law development process?	Yes/No	Innovative governance	

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ID	Indicator definition	Units of measure	Target governance dimension	SDGs
2_25	Do mechanisms exist to address identified gaps in water governance when stakeholders bring them to attention?	Yes/No	Innovative governance	
2_26	Are relevant information, policies, and any changes actively published and shared with stakeholders in all the required languages?	Yes/No	Stakeholder engagement	
2_27	Are there key performance indicators (KPIs) to assess the success of targeted outreach strategies aimed at women, youth, and vulnerable groups?	Yes/No	Stakeholder engagement	
2_28	Are there formal and informal mechanisms to engage stakeholders?	Yes/No	Stakeholder engagement	
2_29	Is the problem definition the result of a joint stakeholder process?	Yes/No	Stakeholder engagement	
2_30	Is the problem definition shared between stakeholders?	Yes/No	Stakeholder engagement	

Source: Own elaboration based on consultations with RETOUCH NEXUS partners.
Notes: * experiments refers to experiments with innovative governance practices including innovative institutional settings, new policy paradigms and new practical tools.

3.4. Hydrological metrics

The next level of metrics corresponds to output variables of hydrological models. RETOUCH NEXUS considers these metrics to be of great importance. In particular, these variables allow quantifying the physical processes and interactions that determine the availability and quality of water (Table 3). Furthermore, estimates of available water resources often rely on these variables and modelling tools[5]. In turn, these estimates provide useful information for the quantification of subsequent RETOUCH NEXUS indicators. Their nature allows application at smaller scales: the local and sub-basin scale.

Table 3. Metrics for measuring hydrological outputs.

ID	Name	Definition	Units of measure	SDGs
3_1	Evapotranspiration (ET)	Measures the amount of water on the earth's surface that is converted to vapour. May be computed as actual evapotranspiration or potential evapotranspiration.	m3 per hectare per year, m3 per hectare per month	
3_2	Aquifer Storage	Measures the amount of water stored on an aquifer. May be computed for shallow aquifer or deep aquifer.	m3 by day/month/year	

[5] For example, the European Commission (2023) provides a list calculation methods and modelling approached for water quantity (See Annex 8o).

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ID	Name	Definition	Units of measure	SDGs
3_3	Phosphorous load	Measures the phosphorous concentration in water flow.	mg/L; mg/m3	
3_4	Nitrate load	Measures the amount of nitrates in water flow.	mg/L; mg/m3	
3_5	Crop Yield	Measures the potential crop harvest taking into account aboveground biomass.	kg/ha	
3_6	Surface runoff	Measures the amount of water applied to the ground that does not infiltrate.	m3	
3_7	Groundwater flow	Measures the amount of water flowing from shallow aquifers to the main channel of a basin or sub basin.	m3/day	
3_8	Water Yield	Measures the capacity of the river basin to provide flowing water.	m3/day	
3_9	Sedimentation	Measures the concentration of sediments in water flow.	mg/L	

Source and Supporting references: Neitsch *et al.* (2011); Francesconi *et al.* (2016).

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3.5. Specific water dimensions

The aim of this sub-collection is to allow assessment of specific areas of importance for water governance. Here, we consider quantitative indicators targeting water scarcity, land use, green water, soil quality, cost recovery and economic productivity (Table 4). All of these are key water dimensions of great importance. Furthermore, these indicators provide useful information for policy making and for understanding progress towards specific goals. While suitable for multiple spatial scales, these indicators will provide valuable information of the 'big picture' at subnational and national scales.

Table 4. Indicators for key water dimensions.

ID	Name	Definition	Units of measure	Target water dimension	Supporting References	SDGs
4_1	Falkenmark or Water Stress Index (WSI)	Measures the amount of available renewable freshwater resources per capita after considering environmental flow requirements. **Sub-indicators:** This indicator may be disaggregated among multiple water sources (groundwater, surface water or recycled wastewater).	Yearly or monthly m3/person	Water Scarcity	Damkjaer & Taylor (2017)	
4_2	Water Withdrawals to Availability ratio (WTA ratio) or Water Exploitation Index + (WEI+)	Measures the consumption of water as a percentage of available renewable freshwater resources. Here, consumption considers domestic, industrial and agricultural water withdrawals. To account for ecosystems, water availability is corrected by subtracting environmental flow requirements. **Sub-indicators:** This indicator may be disaggregated among multiple water sources (groundwater, surface water or recycled wastewater).	Ratio (% of available freshwater)	Water Scarcity	Damkjaer & Taylor (2017) Karabulut *et al.* (2016)	
4_3	Matching Degree of Water Land Resources (MDWL)	This indicator measures the amount of water resources used by agricultural land unit. This is: MDWL = (Total water resources*proportion of	m3/ha	Land use	Zhao *et al.* (2018) Arthur *et al.* (2019)	

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ID	Name	Definition	Units of measure	Target water dimension	Supporting References	SDGs
		agricultural water consumption) / (agricultural area). **<u>Sub-indicators:</u>** This indicator may be disaggregated among multiple water sources (groundwater, surface water or recycled wastewater).				
4_4	Soil Organic Carbon (SOC)	Concentration of soil organic carbon in the top X cm of soil	% on the top X cm of soil.	Green water/Soil Quality	UNCCD & SPI (2019)	
4_5	Soil erosion rate	Refers to the rate at which land surface wears away due to physical forces (rainfall, water, wind, anthropogenic).	tonnes per hectare per year	Green water/Soil Quality	MARD (2023)	
4_6	Water Retention Capacity of Soil	Measures the capacity of the soil to accumulate water.	m3 per hectare	Green water/Soil Quality	MARD (2023)	
4_7	Cost recovery of water services	Measures the percentage of administrative and operating costs of water provision service that is recovered through policy pricing measures. Considers the following sectors: - Energy production. - Agriculture (irrigation). - Domestic consumption. - Industrial Consumption. **<u>Sub-indicators:</u>** This indicator may be disaggregated among multiple water sources (cost recovery of groundwater use, surface water use or recycled wastewater use).	% of water service cost that is recovered through pricing measures	Cost Recovery	OECD (2020)	

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ID	Name	Definition	Units of measure	Target water dimension	Supporting References	SDGs
4_8	Water Economic Productivity	Measures how much water is used to produce a given output (in monetary value). Considers outputs from the following sectors: - Energy production (by energy resource) - Food and agriculture (by commodity). **Sub-indicators:** This indicator may be disaggregated among multiple water sources (groundwater use, surface water use or recycled wastewater use).	m3/$	Economic Productivity	El-Gafy (2017); Arthur *et al.* (2019)	
4_9	Environmental Flow Requirements	Measures the amount (flow) of water required to maintain healthy freshwater-dependent ecosystems in river basins.	Volume (10^6 m3) per month	Healthy ecosystems	Karabulut *et al.* (2016)	

3.6. Pairwise WEFE Nexus interactions

These quantitative indicators provide the main building blocks for understandings WEFE nexus interactions (Table 5). We consider cross-sectoral water allocations (resource flows) and intensities (water footprints). Their importance relies on their ability to capture connections among Nexus Pillars. Furthermore, as proposed by Karnib (2018) quantifying these interactions gives way to a variety of policy analyses. For example, what will happen if, due to climate change, the availability of water resources changes in the future? What will happen to the availability of water resources if the demands for food, energy and domestic consumption increase because of population growth? The Pairwise Nexus interactions adopted by RETOUCH NEXUS provide the starting point to look for answers to these questions. These indicators are mostly scale independent. The opportunity to calculate them depends on data availability at broader or smaller scales. However, computing these indicators at multiple scales gives the opportunity to identify trade-offs and synergies among the Nexus Pillars over multiple scales.

Table 5. Indicators for understanding pairwise Nexus interactions.

ID	Name	Definition	Units of measure	SDGs
5_1	Cross-sectoral water flow quantities	Measures the amount of water used by each sector. Including the following:	Volume (10^6 m3) per month	

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ID	Name	Definition	Units of measure	SDGs
		- Energy related water usage (by energy source). - Food related water usage (by crop/livestock production). - Industrial water usage (excluding energy). - Domestic water usage. **Sub-indicators:** This indicator may be disaggregated among multiple water sources (groundwater use, surface water use or recycled wastewater use).		
5_2	Cross-sectoral Water Use Intensities (Water Footprint)	Measures the amount of water used to produce one unit of output of another sector. Considering the following: - Energy related water usage (by energy source). - Food related water usage (by commodity). **Sub-indicators:** This indicator may be disaggregated among multiple water sources (groundwater use intensity, surface water use or recycled wastewater use intensity).	m3/toe or m3/Wh (Energy), m3/tonne (Food).	

Source: Karnib (2018).

3.7. Joint WEFE Nexus interactions

In this section, RETOUCH NEXUS proposes an adapted version of the water withdrawals to availability ratio that considers water allocations for energy and food taking into account environmental flow requirements (Table 6). Together with the pairwise Nexus interactions, this indicator may be used to capture the main trade-offs and synergies between WEFE Pillars. The difference of the indicator proposed here and the pairwise interactions is that this indicator allows observing the four Nexus pillars together, rather than multiple individual two-way connections. For example, what will happen to the available freshwater resources if water demands for energy or agriculture increase? Will the available water resources be enough to maintain healthy ecosystems? Conversely, if new technologies decrease the demands for water from the energy or agriculture sector, how, will the available water resources evolve? The adapted WEFE WTA Ratio can provide insights to solve these questions. As before, the scale of computations is flexible and depends on data availability.

Table 6. Indicators for understanding joint WEFE Nexus interactions.

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ID	Name	Definition	Units of measure	SDGs
6_1	WEFE WTA Ratio	The WEFE Water Withdrawals to Availability (WTA) ratio is the proportion of available renewable freshwater resources employed for food and energy. To account for ecosystems, water availability is corrected by subtracting environmental flow requirements. **Sub-indicators:** This indicator may be disaggregated among multiple water sources (groundwater, surface water or recycled wastewater). Furthermore, ratios may be computed disaggregating food into different commodities and energy into different sources.	% of available renewable freshwater resources	

Source: adapted from Karabulut *et al.* (2016).

3.8. Composite indicators

Composite indicators are used to provide benchmarks and assess progress towards policy goals, especially on broader scales and longer terms. We propose a selection of composite indicators that are fit for the assessment of water governance within the WEFE Nexus (Table 7). These indicators provide the means to compare different contexts and learn from each other. In addition, their repeated computation over time allows identifying improvement towards achieving previously identified targets. Moreover, by disaggregating the indicator among it's components, policy makers can identify which dimensions exhibit room for improvement.

Table 7. Composite indicators for monitoring water governance.

ID	Name	Definition/Description	Units of measure	Target dimension	supporting references	SDGs
7_1	WEF Nexus Index	Composite indicator using 21 SDG indicators	Composite Indicator (Index)	WEF Nexus	Simpson *et al.* (2022)	
7_2	Nexus Security Risk Index (NESRIX)	Composite Indicator considering the 4 WEFE Pillars. Considers	Composite Indicator (Index)	WEFE Nexus	Sood *et al.* (2019)	

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ID	Name	Definition/Description	Units of measure	Target dimension	supporting references	SDGs
		Institutional Political Socio-economic and Environmental dimensions. Political and Institutional variables rely on surveys.				
7_3	Human Development Index (HDI)	Human Development Index. Composite Indicator considering diverse measures of decent living standards.	Composite Indicator (Index)	Decent living standards	Susnik *et al.* (2022) UNDP (1990)	
7_4	National Water Security Index	Composite Indicator considering 5 dimensions: Rural Household Water Security, Economic Water Security, Urban Water Security, Environmental Water Security, Water-related Disaster Security.	Composite Indicator (Index)	Water security	ADB (2020)	
7_5	Wastewater Reuse Effectiveness Index (WREI)	Composite Indicator that measures bio-physical and institutional components to assess the wastewater treatment environment	Composite Indicator (Index)	Wastewater reuse	Kurian *et al.* (2019)	
7_6	Hydro-Socio-Economic-Environmental-Political Index (HSEEPI)	Compiles eleven sub-indicators including economic, sociology, rural sociology, health and sanitation, tourism, education, research and development, technology, human development, environment and government policies at different spatial scales	Composite Indicator (Index)	WEFE Nexus	Jam *et al.* (2023)	

4. Indicator Framework

In this section, we propose a map for the selected indicators that allows assessing water governance over different spatial and temporal scales. We build on the literature by taking the OECD water governance indicator framework as a starting point and suggesting additional layer of indicators that allow monitoring water governance across multiple scales, levels and sectors over time. We refer to this approach as a multi-level and cross-sectoral reasoning. The idea of this approach is to complement existing monitoring frameworks to allow assessing not only governance set ups, but also their performance and implications. For this reason, we consider not only pure governance indicators, but also indicators related to the multiple aspects of water management. This allows assessing the performance of governance systems and the results and impacts of specific policy interventions over different scales.

We provide two perspectives for our framework: a research perspective (Figure 1) and a policy-making perspective (Figure 2). The two perspectives provide essentially the same information. However,

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following the advice of key experts, we propose two versions: the first one allows identifying our framework in the research landscape and the second, to apply this information to the RETOUCH NEXUS case studies. Following , each subset of indicators serves a different purpose and fits a different spatial and temporal scale. On a first level, our map includes indicators to assess the enabling environment and baseline conditions for good governance in a given context. The second level considers indicators and metrics that assess progress towards policy goals. The third and final level proposes indicators to monitor policy impacts and results over longer periods of time and broader scales. On the other hand, Figure 2 maps the proposed indicators to the spatial scale of the RETOUCH NEXUS project case studies[6] and to the timeline of policy objectives (short and long term).

Independent of the perspective, our framework takes into account the following considerations. Before any assessment, it is always critical to assess the baseline of each indicator. Understanding the baseline helps to identify policy needs and design interventions with better information. In the longer term, the enabling environment may change. As a result, the assessment of RETOUCH Indicators should be revised over time. Additionally, it is also critical to identify the enabling environment. Following our mapping, this can done by using existing frameworks (*e.g.*, OECD, 2018; Melloni *et al.*, 2022).

After a thorough understanding of the baseline conditions and enabling environment, there are two approaches to monitor water governance systems and policy interventions. On the first approach, across temporal scales, one system or intervention may have impacts over the short, medium and long term. At the short and medium term, policy interventions may affect significantly the indicators and metrics that we have classified as hydrological variables, specific water dimensions, pairwise Nexus interactions and joint Nexus interactions. As results, we consider this group useful for assessing progress towards meeting desired objectives. At the longer term, composite indicators serve to assess the impacts of policy interventions.

On a second approach, across spatial scales, an intervention may deliver downward cascading impacts from its implementation at a larger scale (top-down impacts) or upward impacts resulting from up-scaling local practices (bottom-up impacts). To assess these dynamics, RETOUCH NEXUS proposed multiple indicators and metrics. At smaller scales, hydrological variables describe changes on the availability and quality of water. On the other end, at larger scales composite indicators and specific water dimensions (e.g., water scarcity, land use, soil quality, and economic productivity) provide valuable information. Additionally, the pairwise and joint WEFE Nexus interactions may be computed across multiple scales to identify interregional trade-offs. The collection of indicators proposed by RETOUCH NEXUS keeps in mind the two approaches for assessing governance systems and interventions as pathway to cross-sectoral, multi-level and multi-stakeholder water governance.

[6] https://retouch-nexus.eu/case-studies/

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Figure 1 – Map of RETOUCH NEXUS indicators for assessing water governance over different spatial and temporal scales (Research Perspective).

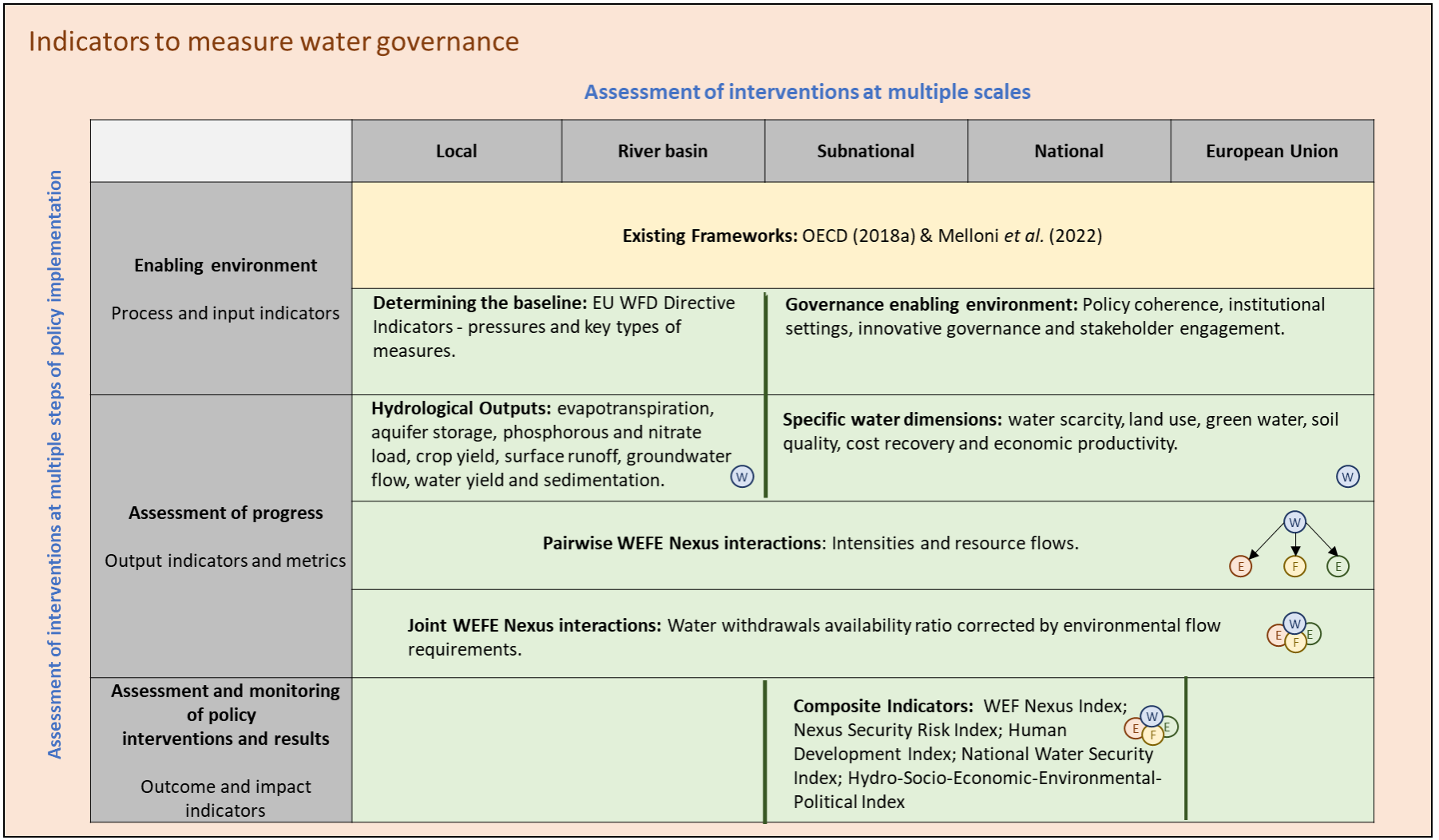

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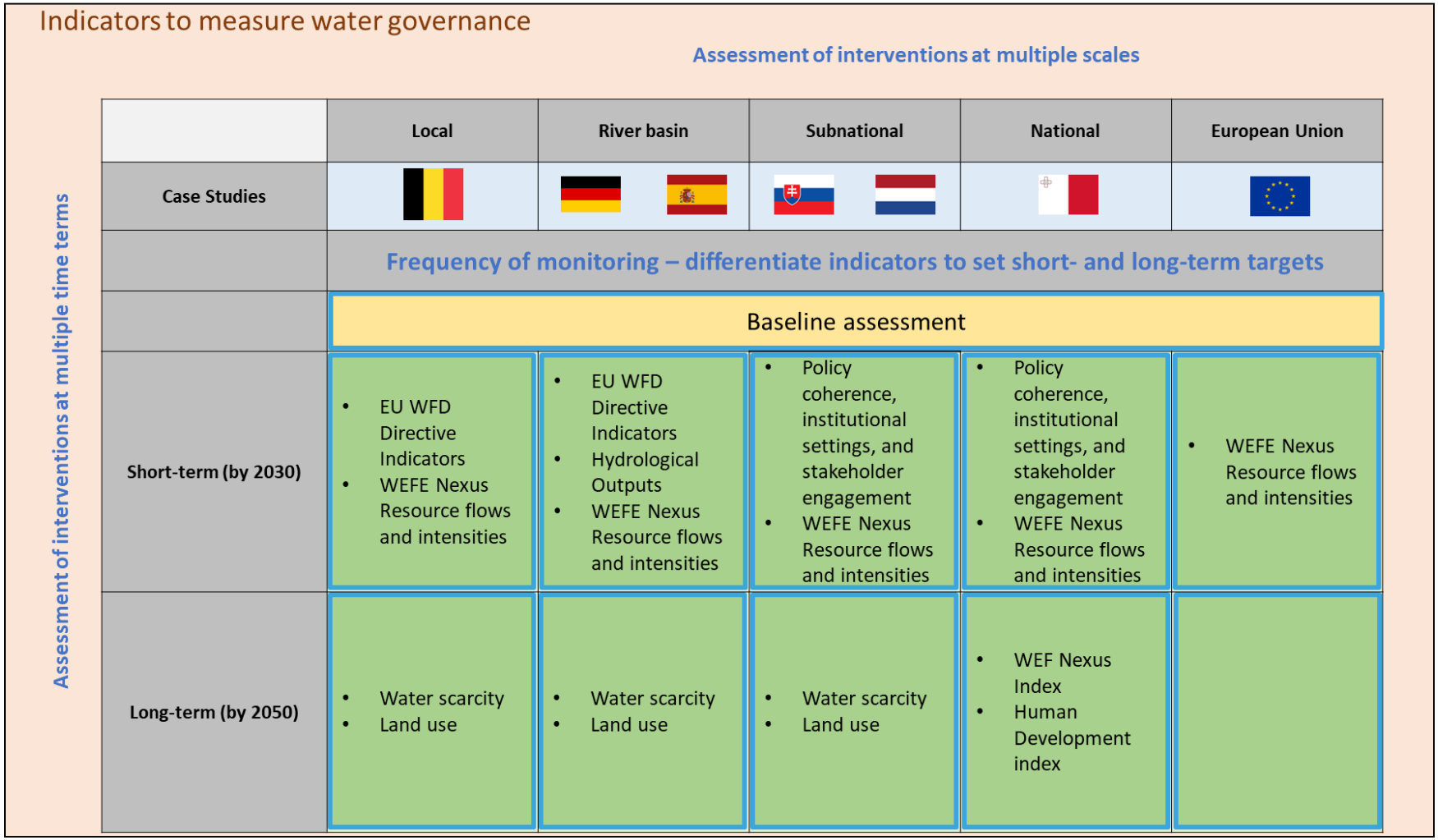
Figure 2 – Map of RETOUCH NEXUS indicators for assessing water governance over different spatial and temporal scales (Policy-making perspective).



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5. Conclusion and final remarks

Throughout this report, we have listed several indicators that are fit for water governance monitoring over multiple spatial and temporal scales. Policy-makers and practitioners may use these indicators on an individual basis by selecting those that fit the specific context. RETOUCH NEXUS brings these indicators together to monitor if (and how) specific water governance arrangements and interventions (*e.g.* economic instruments) deliver policy objectives. We have described these indicators and mapped them in one framework (&2). The collection of indicators proposed by RETOUCH NEXUS reflects the complexity of cross-sectoral, multi-level and multi-stakeholder water governance frameworks.

Multiple studies have highlighted the contribution of the WEFE Nexus approach to the Sustainable Development Goals – SDG's (Liu *et al.*, 2018; Pahl-Wostl 2019). Following this reasoning, we have mapped our indicators to their potential contribution to assess progress towards achieving the SDGs. Figure 3 summarizes this analysis.

Figure 3 – RETOUCH NEXUS Indicators and Contribution to SDGs.

	SDG 2	*SDG 6*	*SDG 7*	*SDG 9*	*SDG 11*	*SDG 12*	*SDG 13*	*SDG 14*	*SDG 15*	*Multiple SDGs*
WFD Indicators	6	15	3	0	8	1	1	0	16	0
Governance enabling Environment	4	4	4	0	0	0	0	0	4	26
Hydrological metrics	1	9	0	0	0	0	0	0	9	0
Water Dimensions	2	8	1	1	3	1	0	1	6	0
Pairwise WEFE Nexus interactions	2	2	2	0	2	2	0	0	2	0
Joint WEFE Nexus interactions	1	1	1	0	0	0	0	0	1	0
Composite Indicators	1	1	1	0	0	0	0	0	1	5
Total	17	40	12	1	13	4	1	1	39	31

During the Next steps of RETOUCH NEXUS, we will apply this indicator framework to the multiple case studies of the project. The idea is to learn from key stakeholders to refine the framework. Furthermore, as advised by key experts during consultations, the application of this framework to case studies represents a strategic opportunity to bridge the gap between research and policy implementation. To do this, we will keep in mind two specific recommendations. First, a careful consideration of when to set the baseline, and second, a thoughtful definition of time planning horizons (short and long term). The ambition is to use this experience to advance towards a better understanding and monitoring of water governance and its implications.

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