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INN WATER

Promoting social innovation to renew multi-level and cross sector water governance

Physical Water Accounts for WEFE nexus CGE models

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INN WATER

EXECUTIVE SUMMARY

This paper analyses the availability of **Physical Water Accounts (PWAs)** into **water or WEFE (Water–Energy–Food–Ecosystems) nexus CGE models** for seven study sites within the InnWater project. **Computable General Equilibrium (CGE)** models represent the economy as a system of interdependent markets, sectors, and production factors, allowing for the evaluation of economic, environmental, and policy impacts. **PWAs** provide the essential physical data on **water extraction** (e.g., surface and groundwater) and **water use** by the economic sectors (e.g., agriculture, industry, and households) required to represent water in CGE models.

Concretely, the paper:

- Presents the **PWAs for six sites**.
- Examines the **limitations imposed by the availability of the SAM** (Social Accounting Matrix) on the development of CGE models at the river basin scale.
- Formulates **key recommendations for the development of Water-CGE** models at the river basin level.
- Presents **a methodology to identify potentially suitable sites** in Europe for which SAMs and PWA may be available.

The seven **study sites in the project InnWater** vary in their geographical and hydrological characteristics. They include river basins defined by hydrological boundaries (Figueres, Seine-Aval, Middle Tisza, Middle Brenta), catchment-based regions in the West Country (Brue and Otter), and island or NUTS2-region basins (Corsica, La Réunion).

Data collection for PWAs employed multiple approaches. For the river basins Middle Brenta and Middle Tisza the river basin authority provided data at basin scale. For two others (Seine-Aval and West Country), approximate or representative regions were defined. For Corsica and Réunion, PWA data were compiled at administrative **NUTS2** level. Comparing the compiled PWAs reveals substantial differences among sites in total water volumes, the balance between groundwater and surface water, and sectoral allocation. **Agricultural irrigation and piped water production** account for a major share of total water use (25 to 80%), while industrial demand depends on the local economic structures and activity levels.

Although PWAs could be derived—under consistent assumptions— for six of the project study sites, the **development of CGE models** remains limited by the availability of **Social Accounting Matrices (SAMs)**, which provide the database for such models. To design **water or WEFE nexus CGE models** at the river basin scale, **identifying representative CGE regions** is essential. When compatible economic datasets and PWAs are absent or costly to assemble, **data collection** can become a major constraint. Thus, decisions should be based on a **cost–benefit assessment** of model precision versus data collection costs.

Within the **European context**, using **hydrological regions that align with administrative boundaries (e.g., NUTS2)** offers a promising and pragmatic strategy. At these levels, PWAs and corresponding regional SAMs are often available, facilitating integration and comparability. **Linking hydrological and administrative units** enhances feasibility and reduces data collection costs. It supports the wider development of **Water-CGE or WEFE nexus CGE models** for more integrated economic–water policy analysis within the European water governance objectives and the United Nations' Sustainable Development Goals (SDG).

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ACRONYMS

CGE model:	Computable General Equilibrium model
PWA:	Physical Water Accounts displaying data of water extraction and usage
PWA area:	Area for which the PWA data represent water extraction and usage
RBD:	River basin district
SAM:	Social Accounting Matrix
t.b.c:	To be confirmed
WEFE nexus:	Water, Energy, Food and Ecosystem nexus
M m^3:	million cubic metres
m^3:	cubique metres
km^2:	square kilometres
NUTS:	Nomenclature of territorial units for statistics

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Project Consortium

1. INTRODUCTION

Computable General Equilibrium (CGE) models are quantitative economic frameworks that represent an entire economy as a system of interdependent markets, agents, sectors, and production factors. They are widely applied for impact analysis, policy evaluation, and economic assessment. CGE models facilitate the examination of the effects of economic or policy changes (e.g., variations in prices or taxes) as well as environmental changes (e.g., impacts induced by climate change). Such models can be developed at different spatial scales, including global, national, and subnational levels.

Within this context, **WEFE nexus CGE models** are specifically designed to analyse research questions related to the four pillars of the Water–Energy–Food–Ecosystems (WEFE) nexus (Beaumais et al., 2024). **Water CGE models**, on the other hand, address research questions primarily concerning water-related issues. In both, WEFE nexus and water CGE models, water can be represented in various functional roles within the economy.

Water may be modelled as a **final consumption commodity**, such as piped water consumed by households; as an **intermediate commodity**, used by producers as an input in production processes; or as a **production factor**, representing raw water employed directly in production (e.g., surface water for agricultural irrigation or groundwater used by water suppliers to produce piped water). Additionally, water can be represented as an **environmental indicator**, reflecting aspects such as water resource levels or pollution (Henseler et al., 2025).

The representations of water as a final or intermediate commodity and as a production factor are directly incorporated into the CGE model's structure. In contrast, modelling water as an environmental indicator requires extending the CGE framework through the inclusion of an **environmental satellite account**. Satellite accounts are supplementary datasets linked to the CGE model's database—typically the **Social Accounting Matrix (SAM)**. Unlike SAMs, environmental satellite accounts are not required to maintain monetary consistency and may include non-monetary data, such as physical water quantities. Further methodological details can be found in Henseler (2025 a).

Figure 1 schematically illustrates the conceptual framework of WEFE nexus and CGE models. The blue arrow on the grey background represents the flow of raw water information. Water data enter the CGE model through the SAM, where water is represented as a final consumption good for households, an intermediate input for industries, and a production factor (e.g., groundwater or surface water). The production factor "water" directly enters production processes, while piped water produced by the water sector is supplied to households and industries for consumption and production, respectively.

CGE models are built on macroeconomic data, typically organised in SAMs. Developing WEFE nexus or water-specific CGE models therefore requires the integration of corresponding water data into the SAM. The necessary SAM may either already exist or need to be constructed from scratch—a process that involves extensive data collection and processing (Henseler, 2025 a).

Integrating water data into a SAM requires information on the **economic values** of water in its roles as a commodity and as a production factor. When such economic values are not directly available, they can be derived from **Physical Water Accounts (PWAs)**. A PWA provides information on the physical volumes of water extracted from the environment, used within the economy, and returned to the environment (United Nations, 2012). PWAs offer several key insights:

- They quantify water extraction and usage across economic sectors.
- They reveal the dependence of specific sectors on freshwater resources.
- They help assess the relative importance of water resources to different sectors.
- They provide a data foundation for integrating water into CGE model frameworks.

This paper presents a methodological approach for deriving CGE model data from PWAs and evaluates the availability of such accounts for the seven case study sites of the **InnWater Project**.

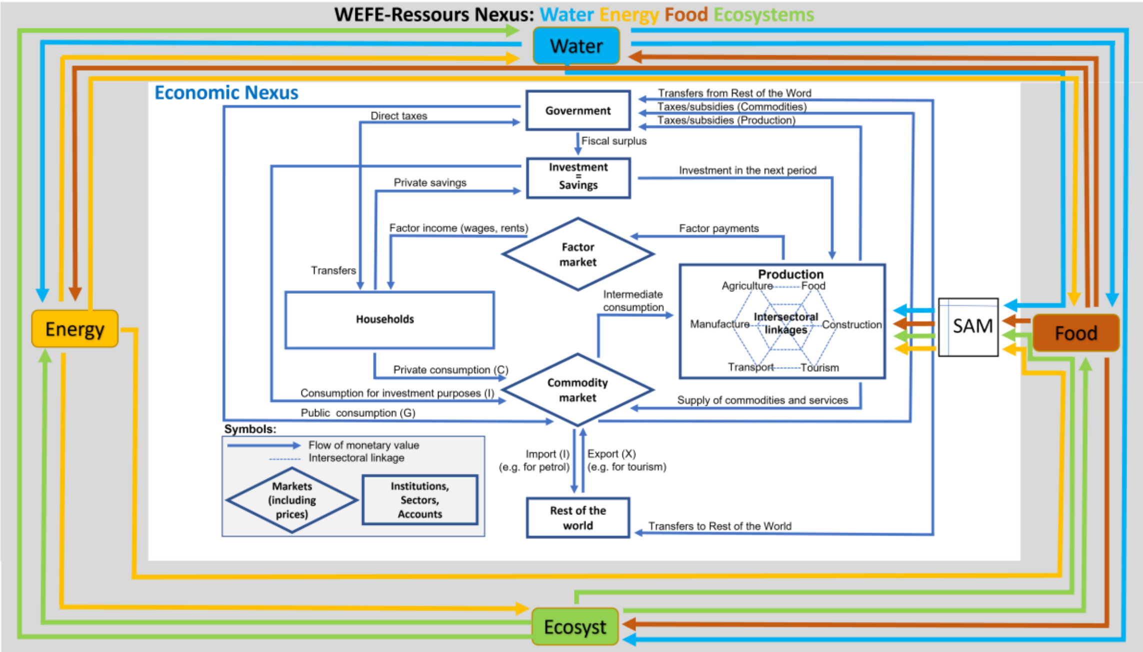

Figure 1: WEFE nexus and CGE model.
Source: adapted from Henseler et al. (2022)

2. METHODOLOGY

2.1 Conceptual framework

2.1.1 Physical Water Accounts

Physical Water Accounts (PWAs) are typically developed at national and subnational levels, such as for administrative regions or river basins. The spatial scale and level of detail depend on the intended purpose—such as policy support, water resource planning, or environmental assessment—and on data availability (United Nations, 2012).

At the **national level**, PWAs are aligned with national statistical systems, economic accounts, and international reporting frameworks, notably the *United Nations System of Environmental-Economic Accounting for Water (SEEA-Water)*.

At the **subnational or regional level**, PWAs may be compiled for administrative units (e.g., provinces, counties) or for hydrological regions (e.g., river basins). Regional PWAs provide critical information for water resource management, allocation planning, and sustainability assessments—functions often closely linked to administrative and hydrological boundaries. The **EU Water Framework Directive (WFD)** obliges Member States to define river catchment regions as the basis for water management (European Commission, 2000). To support sustainable and quantitative water resource management, water and river basin managers are required to compile water balances for the corresponding river basins (European Commission, 2015). Thus, the legislative framework ensures the existence of water balances for the river basin management units in Member States.

Local-level PWAs also exist, offering highly detailed information on water use and extraction. These accounts can refer to municipalities, urban water systems, or irrigation districts. Local PWAs are particularly valuable for informing water-use efficiency programs and sustainability measures at the municipal or district level. Below this scale, **point-level accounts**—which record data for individual extraction sites—constitute the most granular level of measurement. When comprehensive data at the local or point level are available, they can be aggregated to represent larger administrative or hydrological regions.

Highly detailed PWAs can depict **water flow structures**, as illustrated schematically in Figure 2 through a water flow chart. For integrating information on water extraction and use into **water-focused CGE models**, such detailed datasets are especially valuable if they can be aggregated consistently. The development of CGE models typically requires water data to be aggregated to a level compatible with the model's economic and sectoral resolution.

Figure 3 illustrates an aggregated representation of water flows that can be integrated into a CGE model. These flows encompass the main sources of freshwater—such as groundwater and surface water—and the principal categories of water users, including piped water suppliers, agriculture, industry, and households. In some cases, additional water sources (e.g., tidal or seawater) may also be considered.

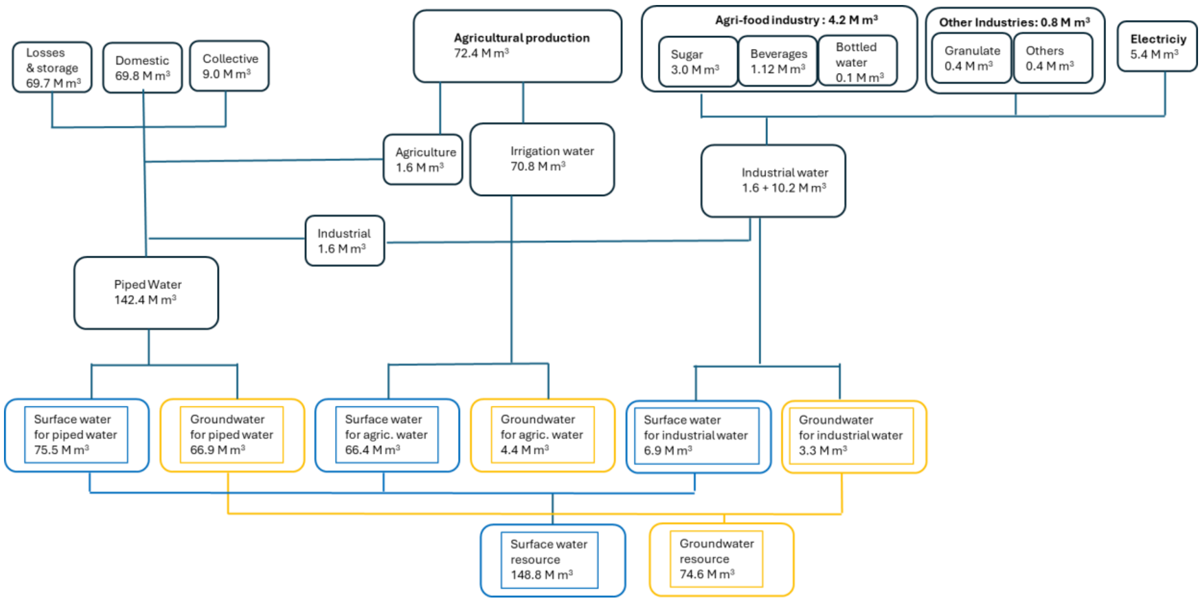

Figure 2: Detailed scheme of water flows (exemplarily for Réunion)
Source: Own presentation based on data from Office de L'Eau (2019 a-d, 2022)

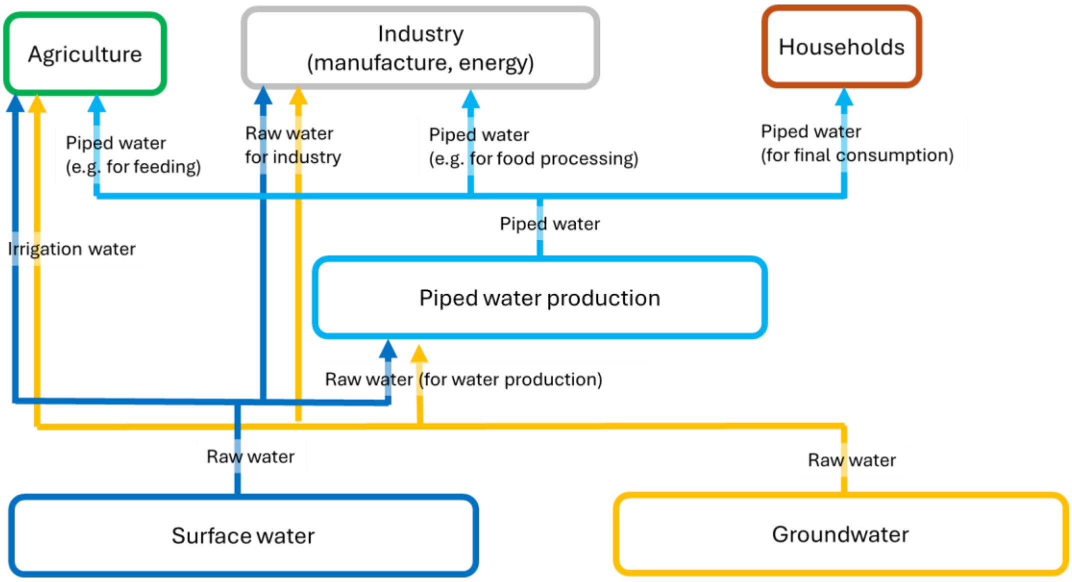

Figure 3: Simplified scheme of water flows for PWA (generic)

2.1.2 Derive water data for SAM

While data in **Physical Water Accounts (PWAs)** are expressed in physical volume units (e.g., cubic metres), the database underlying a **Computable General Equilibrium (CGE)** model—namely, the **Social Accounting Matrix (SAM)**—requires information in **monetary values**. In a SAM, the monetary values associated with commodities and production factors represent the product of quantity and price (for commodities) or the product of quantity and cost (for production factors), as shown in Equation (1):

$$WATER_{value}[€] = WATER_{quantity}[m^3] \times WATER_{price}[€/m^3] \qquad \textit{(Eq. 1)}$$

The PWA provides information on water quantities, which can be converted into monetary values by multiplying the quantities by the corresponding per-unit price of water as a commodity or by the per-unit cost of water extraction.

As previously noted, when the PWA and SAM differ in their **sectoral or spatial resolution**, adjustments through **disaggregation or aggregation** are required to achieve compatibility. The economic sectors represented in the PWA and the SAM must be mapped at comparable levels of detail.

In principle, this mapping can be accomplished in three ways:

1. **Disaggregation** – splitting aggregated values in the PWA (or SAM) into more detailed categories;
2. **Aggregation** – combining detailed accounts from the PWA (or SAM) into broader categories; or
3. **Hybrid approach** – applying both disaggregation and aggregation, depending on data availability.

In practice, adjusting data on the **PWA side** is often more feasible, as splitting or aggregating SAM accounts can require substantial effort and detailed auxiliary data. Conversely, aggregation within the SAM may lead to a loss of informational richness.

Because per-unit water prices or extraction costs are typically low, the computed monetary values of water in the SAM may appear small relative to other accounts. If these values are disproportionately low compared to other key components (e.g., major production factors), **assumptions or scaling adjustments** may be necessary to ensure that the water representation remains interpretable and meaningful within the CGE framework. Further methodological guidance is available in Henseler (2025 a).

2.2 Data

PWA data are generally available in databases or published reports for larger administrative regions, such as at the **national** or **subnational** level. For administrative units (e.g., provinces or regions), PWA data are often readily accessible and can be downloaded directly or extracted from official publications. Table 1 provides an illustrative overview of databases offering PWA data for selected regions at different spatial levels.

Research questions concerning **water governance, management**, or other **hydrological issues** are frequently addressed at the level of **hydrological regions**, such as river basins. PWAs for river basins often exist as part of water management and monitoring systems and are, for instance, required under the **EU Water Framework Directive (WFD)**. When PWA data for hydrological regions are not publicly available, they must be obtained from the competent **river basin authorities** or compiled from available datasets.

For **smaller study regions**—such as sub-basin areas or local districts—where PWA data are unavailable, relevant information can be collected from **municipal-level sources**, **urban water systems**, **irrigation districts**, or **extraction-point datasets**. These data are typically managed by responsible administrative or water management organisations. However, compiling a new PWA through direct data collection or formal data requests can be **resource-intensive**, both in terms of cost and labour.

The **feasibility** of developing a **water** or **WEFE nexus CGE model** therefore depends on the **availability of both the SAM and the PWA**. In many cases, SAM availability poses a more significant constraint. For regions where PWA data exist but no SAM is available, the SAM must be constructed from scratch, which substantially increases development costs. Consequently, the decision to build a CGE model should be evaluated carefully from a **cost–benefit perspective**.

An alternative to developing new datasets is to select a **study region** for which both SAM and PWA data already exist and which can serve as a reasonable **approximation** of the target study area. Small to moderate deviations between the actual study region and the proxy region may be acceptable. When the study region is very small (e.g., a sub-basin or a few administrative districts within a river basin), the next higher spatial level with available PWA data can be used as a **representative region**. However, this involves stronger assumptions—namely, that the representative region accurately reflects the water extraction and usage patterns of the study region.

From a **CGE modelling perspective**, simulations based on an approximated or representative region can still yield sufficiently representative results. Using such regions is often a **cost-effective alternative** to collecting new PWA or SAM data. However, this approach is only valid if the representative region adequately reflects the **hydrological and sectoral realities** of the study area. If significant differences exist—for example, if the study region is characterised by highly groundwater-dependent, intensive agriculture, whereas the representative region relies predominantly on surface water for extensive farming—the representativeness of the PWA becomes questionable, and the approximation may no longer be valid.

Table 1: Data source providing PWA data for different regions (selected examples, not exhaustive list)

Name	Regional coverage	Resolution	Dataset	Source
Eurostat	European Member States	National	Water statistics at national level	Eurostat (2025) Database. Environment (env) > Water (env_wat) > Water statistics at national level (env_nwat)
	Europe	River basin	Water statistics at river basin level	Eurostat (2025) Database. Environment (env) > Water (env_wat) > Water statistics at river basein level (env_rwat)
BNPE	France	National, NUTS2, NUTS3, municipality	Water abstraction and usage	BNPE (Banque nationale des prélèvements quantitatifs en eau) (2025) : Rechercher des données
DEFRA	England	National, NUTS2	Estimated abstractions from [RAW WATER TYPE] by purpose and Environment Agency regional charge area: 2000 – 2015	Department for Environment, Food and Rural Affairs (DEFRA)

3. RESULTS

3.1 Data research and collection

3.1.1 Availability of PWA Data for the InnWater Project Sites

In the following, we present the availability of **Physical Water Account (PWA)** data for seven sites of the *InnWater* project. In this analysis, only **groundwater** and **surface water** are considered as sources of water extraction, while **coastal water** is excluded. Regarding **water use**, we focus on three main categories: **irrigation**, **piped water production**, and **industrial production** (including other economic uses and water for cooling in energy production).

Accordingly, three **water user groups**—**agriculture**, **industry**, and **households**—are retained for illustration and for ensuring comparability among the PWAs of the different sites. Some potential water users, such as **tidal water for electricity production**, involve the use of water in volumes that far exceed the quantities of freshwater typically represented in PWAs for agricultural and industrial use. Consequently, distinguishing between the very large volumes of water used for hydropower generation and the relatively small quantities of freshwater within a single PWA is problematic.

Nevertheless, for the development of **site-specific WEFE nexus CGE models**, a more detailed differentiation of **water types** (e.g., inclusion of coastal water) or **water users** (e.g., hydropower generation, food-processing industries) may be necessary (see Henseler, 2025 a).

Table 2 summarizes the results of the PWA data research conducted for the seven *InnWater* sites. The PWAs differ in the type and method of data collection as well as in the definition of the respective PWA regions. Specifically:

- For **two sites (river basins)**, data were obtained from online databases that exactly match the study regions (i.e., Reunion and Corsica)
- For **two sites (river basins)**, data were collected from online databases defining one **approximative** and one **representative** region (i.e., Seine-Aval and West Country)
- For two sites, **abstraction data** were collected at a **lower spatial level** and subsequently **aggregated** to match the precise boundaries of the study sites (i.e., Middle Tisza Region and Middle Brenta Basin)
- For one site, no suitable approximative or representative region with available PWA data could be identified, and the **costs of data collection** were too high (i.e., Figueres)

Table 2: Regional attributes of the sites and availability of PWA data

Site	Site ID	Country	Study region	Admin. region	PWA	Match/ proxy	Data source type	Source
La Réunion	PS1	FRA	RB	NUTS2	Y	Match	Data base	BNPE (2025)
Middle Brenta Basin	PS2	ITA	RB	RB	Y	Match	Collection	Laghetto, G. (2025) Email
Figueres	PS3	ESP	RB	RB	N	No data	NA	NA
West Country	PS4	GBR	RB	RB	Y	Representative	Data base	DEFRA (2025)
Middle Tisza Region	PS5	HUN	RB	RB	Y	Match	Collection	Kis, A (2025) Email
Seine-Aval	RS-FRA1	FRA	RB	NUTS2	Y	Approximative	Data base	BNPE (2025)
Corsica	RS-FRA2	FRA	RB	NUTS2	Y	Match	Data base	BNPE (2025)

3.1.2 Case Examples for approximative and representative regions

Figure 4 illustrates the **Seine-Aval sub-basin** (shown in deep sky blue), which forms part of the **Seine River Basin District**, located in the **northwest of France**. Figure 5 presents the **Seine-Aval sub-basin** together with the **administrative departments** (European NUTS3 level). To approximate the Seine-Aval sub-basin using administrative boundaries, it is assumed that the **departments of Seine-Maritime and Eure** (outlined in red) are almost entirely contained within the Seine-Aval basin, even though small portions of these departments lie outside it. Conversely, parts of the Seine-Aval sub-basin extend into neighbouring departments. The **Eure-et-Loir department**, for instance, overlaps with the Seine-Aval basin by approximately 50%. For simplification and comparability, we assume that **Seine-Maritime** and **Eure** are **fully included** in the area relevant for the **PWA**, while **Eure-et-Loir** is **excluded** from the Seine-Aval PWA. We call the area defined as relevant for the PWA the "**PWA area**"., which is an **approximative region.**

Figure 6 presents the **West Country study area** (shown in blue), located in the **South West of England**. The **West Country** consists of the **South West administrative region** (European NUTS1 level) and parts of the neighbouring **Severn administrative region**. An exact match for the PWA could only be obtained through **primary data collection** on water abstraction at the **river basin level**. Therefore, for the present analysis, the **South West region** is used as a **representative area** to define the **PWA area** for the **West Country PWA**, as shown in Figure 7. This approach assumes that the overall **hydrological and water-use conditions** in the South West region **reasonably approximate** those across the entire West Country region.

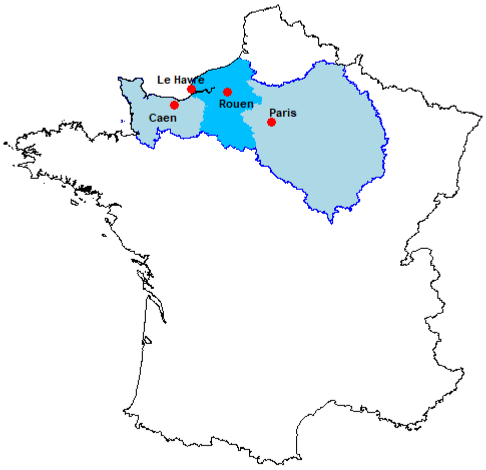

Figure 4: The river basin Seine in blue and Seine-Aval (deep sky blue) in France

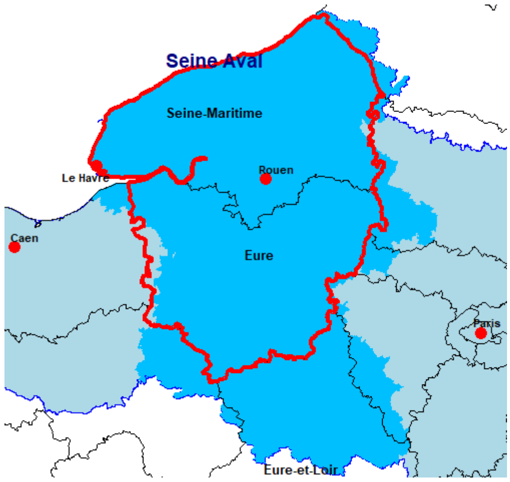

Figure 5: The Seine-Aval river basin (deep sky blue) and the region defined as relevant for the Seine-Aval PWA (delineated in red)

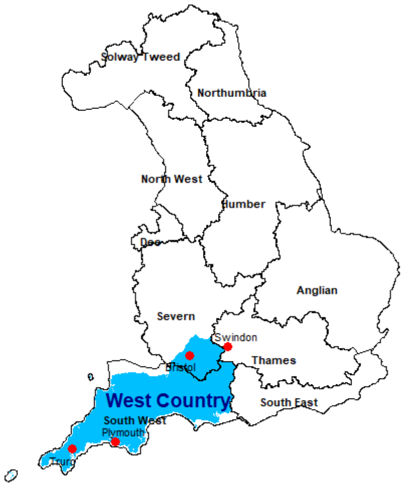

Figure 6: West Country (deep sky blue) in England

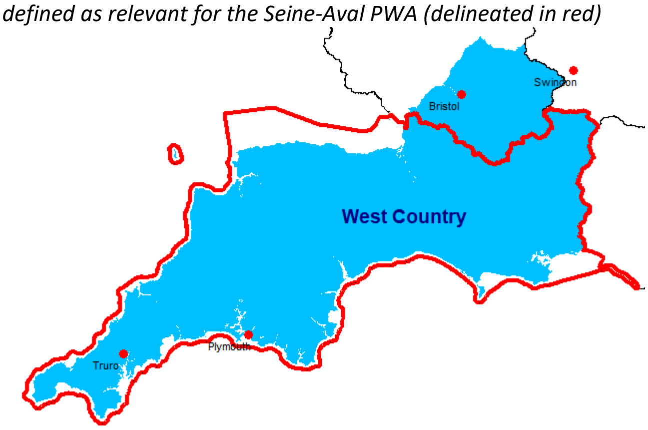

Figure 7: The West Country (deep sky blue) and South West region defined as PWA area for the West Country (delineated in red). Note: The white area within the red borders are costal water which are excluded from the PWA.

3.2 Comparative Analysis of Water Flows Across Sites

Figures 8–13 present **Sankey diagrams** depicting PWA data for six *InnWater* sites, respectively the PWA area defined as representative for the sites. The resulting PWA can be used to construct water- or WEFE nexus–oriented CGE models. Each diagram shows **water extraction** (groundwater and surface water) on the left-hand side and **economic water use** on the right-hand side. These figures allow for both qualitative and quantitative comparison of water extraction and usage patterns among the sites.

These Sankey charts present only **selected types of water sources and uses**. Some orginal PWA datasets include also additional categories for both water sources (e.g., coastal water) and water uses (e.g., hydroelectricity, fish farming, navigation channels, ecological usage). We selected the water types sources and uses to ensure that the **diagrams remain interpretable, consistent, and comparable**. We excluded water uses with extremely high quantities (such as hydroelectric power production or water used in navigation channels), as their inclusion would render the volumes of other economic sectors represented in the CGE model (e.g., agriculture, industry, piped water use) visually negligible in the Sankey chart. Consequently, the PWAs presented as Sankey charts display only **a subset of the full PWA** dataset, which can be considered when focussing the analysis on individual sites.

The **absolute magnitudes** of total water flows differ considerably, ranging from approximately **100 million m³** in *Corsica* to **500 million m³** at in *West Country* and to **850 million m³** at in *Middle Brenta*. The composition of extracted **raw water resources** also varies notably:

- In *Réunion*, **groundwater** and **surface water** are extracted in roughly equal proportions.
- In *West Country*, *Middle Tisza*, *Middle Brenta* and *Corsica*, **surface water** dominates total extraction.
- In *Seine-Aval*, by contrast, the majority of withdrawals come from **groundwater** sources.

These extraction shares reflect the **relative economic importance** of different water resources. For instance, in *La Réunion, Middle Brenta and Middle Tisza* the balance between sources suggests flexibility for reallocation under water stress. In *West Country* and *Corsica*, the underutilisation of groundwater indicates potential for expansion. Conversely, in *Seine-Aval*, the dominance of a groundwater may indicate potential for expansion of surface water usage.

The **distribution of water use** across economic sectors also varies among sites. In all locations, **piped water production** by the water sector constitutes a substantial share of total water use. This production typically draws on both groundwater and surface water in varying proportions (often between 25% and 75%), except in *Seine-Aval* and *Middle Brenta* where piped water is almost exclusively produced from groundwater.

Industrial water use (including energy production) accounts for approximately **20%** of total withdrawals in *West Country*, *Seine-Aval*, and *Middle Tisza*, reflecting their more developed industrial bases. On the islands of *La Réunion* and *Corsica*, and in *Middle Brenta* by contrast, industrial activity represents **less than 10%** of total water use.

Agricultural irrigation constitutes another major component of water use in *Réunion*, *Middle Tisza, Middle Brenta* and *Corsica*, ranging from **25% to 80%**. In most cases, irrigation relies primarily on surface water. In *West Country* and *Seine-Aval* irrigation water use is marginal, reflecting climatic conditions and agricultural systems that rely primarily on precipitation rather than artificial irrigation.

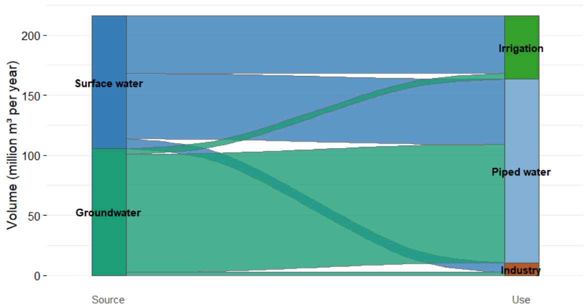

Figure 8: Water extraction and use in Réunion in 2020

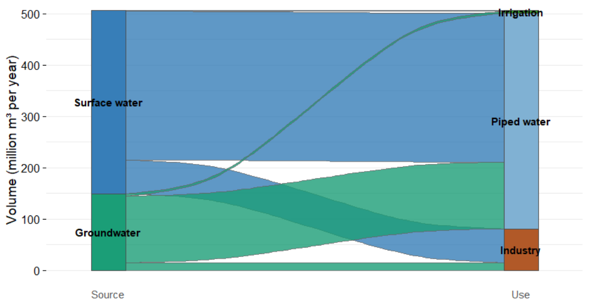

Figure 9: Water extraction and use in West Country in 2015

Figure 10: Water extraction and use in Middle Tisza Basin in 2020

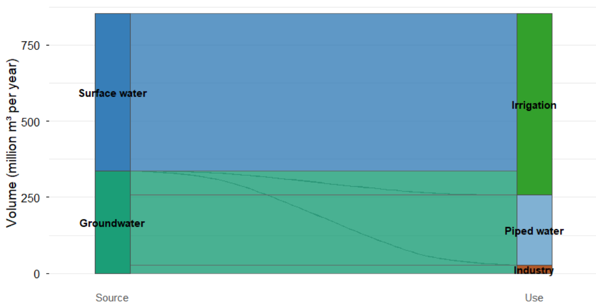

Figure 11: Water extraction and use in Middle Brenta Basin in 2025 [a]

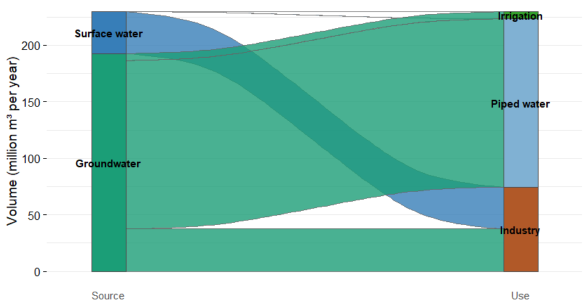

Figure 12: Water extraction and use in Seine-Aval in 2020

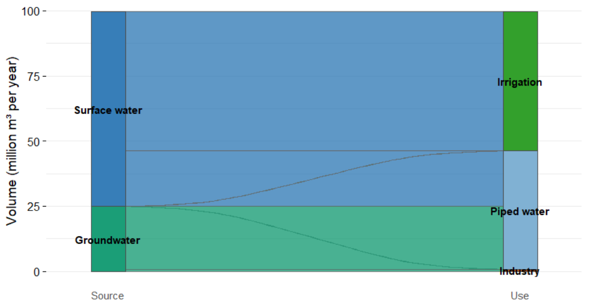

Figure 13: Water extraction and use in Corsica in 2020

Notes: These Sankey charts present only selected types of water sources and use. The PWA data provide more data for water sources (e.g., costal water) and uses (e.g., hydroelectricity, fish farming, channels). We selected the water sources and uses to make the diagrams interpretable, uniform and comparable.

a) *In the PWA for Middle Brenta domestic extraction of ground water is aggregated with the usage as industrial piped water.*

4. WATER-CGE MODELS IN EUROPE

The analysis presents PWA for the InnWater study sites with available data. For this purpose, the corresponding PWA area had to be defined, and data on water extraction and usage had to be available or collected. Developing a **Water-CGE model** (or a **WEFE nexus CGE model**) requires, in addition to the PWA data, the availability of macroeconomic data — ideally in the form of a **Social Accounting Matrix (SAM)**. If a SAM is not available, the cost of collecting data to construct a regional SAM may be too high for a CGE model development project (see Henseler, 2025 b).

To identify potential sites (river basins) in Europe that could serve as case studies for developing a CGE model, the following conditions must be fulfilled:

1. The river basin to be modelled has available PWA data.
2. The river basin to be modelled has an available SAM.

The potential to model river basins in Europe using a Water-CGE model therefore depends on the existence of both PWA data and a SAM. While extraction and usage data for PWA are typically available at the level of **River Basin Districts (RBDs)** or at **regional administrative levels** (e.g., NUTS2 levels), regional SAMs are available only at regional levels for specific administrative districts (see García-Rodríguez et al., 2023, 2025).

If an administrative region (with available **PWA data** and **SAM data**) can be considered sufficiently representative of a river basin, then a Water-CGE model could potentially be developed for that basin. Or, in other words a **PWA area** can be defined for which a **representative SAM** could be available.

As an indicator of representativeness, the **intersecting area** between the river basin and the regional administrative area can be used. The river basin area is defined by **River Basin Districts (RBDs)**,[1] for which geographical data exist at the European level (e.g., EEA, 2025 RBD dataset) or in national repositories (e.g., Datagouv, 2025). For administrative regions (NUTS2), corresponding data can be found in Eurostat (2025). The availability of SAMs can then be checked for the identified RBD-NUTS2 pairs using sources about regional SAM, like García-Rodríguez et al., (2023, 2025).

Figures 14 to 18 illustrate the two-step identification procedure exemplified for French RBDs. Figure 14 presents the French RBDs delineated in blue; Figure 15 shows the French NUTS2 regions delineated in red; and Figure 16 displays their overlapping areas. By visual inspection, several matching RBD-NUTS2 combinations can already be identified — for example, **Vilaine et Côtière Bretagne** with the region **Bretagne**.

To filter the potentially suitable regions, we define in a first step a quantifiable indicator: **the share of the intersecting area of the RBD**, representing how much of the RBD is covered by the overlapping NUTS2 region. A higher share of intersection means that a larger portion of the RBD lies within a single NUTS2 region. Therefore, the NUTS2 region (and its associated SAM) can be considered more representative for the RBD. In this study, we assume that when at least **60% of an RBD** lies within a NUTS2 region, the NUTS2-based economic data can be regarded as sufficiently representative for the basin.

Figure 17 presents the computed intersection shares, using the threshold of 60% as the criterion for further analysis. The map shows that increasing this threshold reduces the number of identified RBDs. The highest shares of intersection are observed for **Vilaine et Côtière Bretagne** with the NUTS2 region **Bretagne** (91%), as already identified visually. The **Côtière Normande** and **Moselle–Sarre** RBDs also show high intersection shares with the NUTS2 regions **Basse-Normandie** and **Lorraine**, respectively.

In a second step, we select intersection areas that result from a single RBD (or a merger of several RBDs) and that together represent **at least 75% of the NUTS2 region**. This ensures that the

[1] River Basin District is meant here in the sense of a sub-river basin district.

economic data of the NUTS2 region (e.g., the SAM) are approximately representative for the hydrological basin.

Figure 18 shows the reduced number of RBD–NUTS2 intersections that meet both conditions:

1. at least 60% of the RBD lies within a NUTS2 region, and
2. one or several intersecting RBD areas cover at least 75% of the NUTS2 region.

In northern France, these criteria identify several promising regions (e.g., in Bretagne and in Normandy). In the north-east and south-east of France, aggregated intersections of multiple RBDs represent over 75% of the corresponding NUTS2 regions. Such aggregated analyses can also be performed when extended hydrological regions are of interest for research or policy purposes.

Table 3 compares and evaluates the potential for developing CGE models among eight selected RBD-NUTS2 intersection matches. We compute a **representation score** by summing the intersection share from Step 1 and Step 2. For aggregated cases, an **average score** is obtained by dividing the total by the number of aggregated areas. The table ranks the RBD-NUTS2 combinations according to their average scores and shows the intersection area (in km²) as a measure of region size. **Bordering countries** are also indicated, as these may affect **representativeness of the hydrological region**: hydrological water regions that cross borders might include only the French portion as a complete French administrative unit of an international river basin, limiting hydrological completeness.

Based on this analysis, the **Alsace–Rhin Supérieur** RBD–NUTS2 pair shows the highest intersection score but borders Germany and represents a relatively small area (< 8,000 km²). Other aggregated river basins have the four lowest scores and covering with 12,000–20,000 km² larger areas: However, thy also border other countries, meaning they may not fully represent the entire hydrological system. In contrast, the RBD–NUTS combinations in **northern France** (Normandy, Bretagne) and **Île-de-France** do not border other countries and cover substantial areas (10,000–27,000 km²), making them promising candidates for developing Water-CGE models. Once these sites are identified, the next step is to verify whether regional SAMs are available for the corresponding NUTS2 regions and whether these regions are of research or policy interest.

The method presented for selecting French river basins as potentially suitable for Water-CGE model development can be applied analogously to other European countries. However, the matching between RBD and NUTS2 regions may differ significantly from France, since the size of NUTS2 regions is determined by **population criteria**, while RBDs are defined by **hydrological boundaries**. In France, a relatively evenly distributed population leads to NUTS2 regions that are roughly similar in size to RBDs. In countries with smaller populations or simpler hydrology (e.g., Hungary), RBDs will likely be **larger** than NUTS2 regions (covering multiple NUTS2 units). In contrast, in countries with larger populations or more complex, fragmented hydrology (e.g., Germany), RBDs will tend to be **smaller** or **split across multiple NUTS2 regions**.

Thus, identifying RBDs that can be economically represented using NUTS2-level data requires a **country-specific analysis** of the spatial correspondence between RBDs and NUTS2 regions.

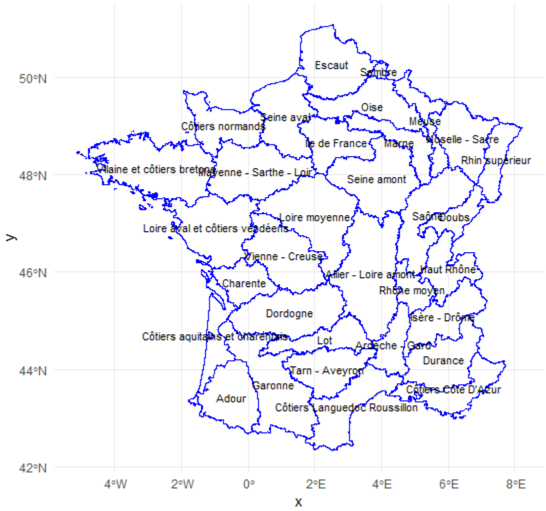

Figure 14: French river basin districts.
Source: Own presentation based on data from Datagouv (2025)

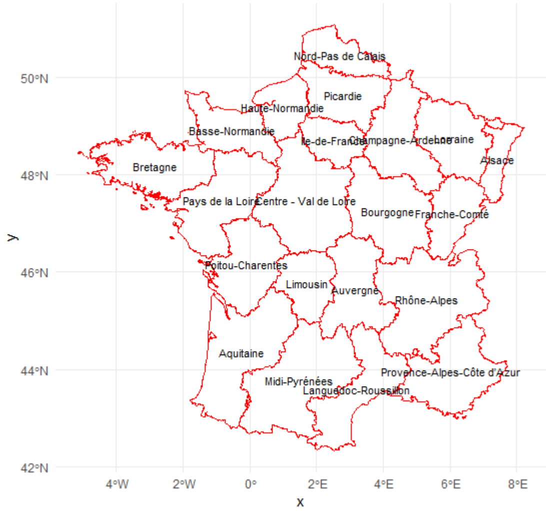

Figure 15:French NUTS2 in their borders of 2016.
Source: Own presentation based on data from Eurostat (2025 b)

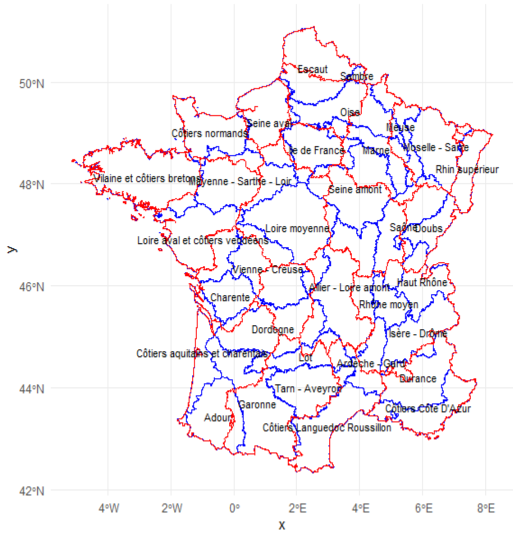

Figure 16 Overlapping river basin districs (in red) and NUTS2 regions (in blue).
Source: Own presentation based on data from Datagouv (2025) and Eurostat (2025 b)

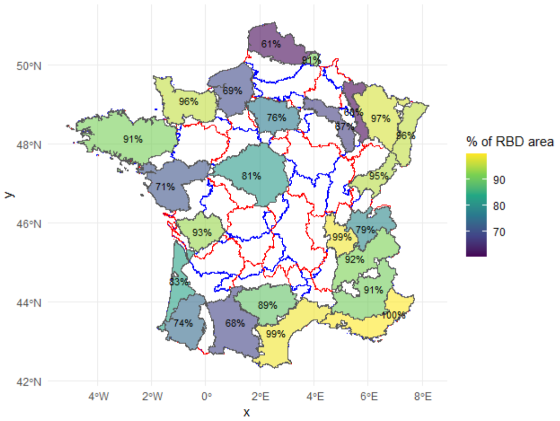

Figure 17: Step 1: Intersections ≥ 60% of RBD Area. River basins where a single NUTS2 region covers ≥60% of the basin area.
Source: Own computation based on data from Datagouv (2025) and Eurostat (2025 b)

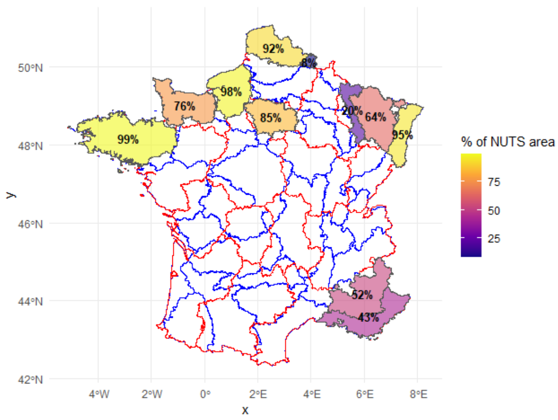

Figure 18: Step 2: Intersections ≥ 60% of RBD & intersections ≥ 75% of NUTS2 area.
Source: Own computation based on data from Datagouv (2025) and Eurostat (2025 b)

Table 3: RBD-NUTS2 intersection areas ranked according to their intersection ranking score.
Source: Own computation based on data from Datagouv (2025) and Eurostat (2025 b)

NUTS	RBD	Intersection area in km2	Percent share of		Intersection ranking score			Borders with bordering country (shared river-basin)
			RBD	NUTS	Single	Agggre-gated	Average	
Alsace	Rhin supérieur	7873	95.9	94.8	190.7	190.7	190.7	Germany
Bretagne	Vilaine et côtiers bretons	27093	91.3	99.1	190.4	190.4	190.4	NA
Basse-Normandie	Côtiers normands	13528	96	76.5	172.5	172.5	172.5	NA
Haute-Normandie	Seine aval	12044	68.8	98	166.8	166.8	166.8	NA
Ile-de-France	Ile de France	10174	76.2	84.6	160.8	160.8	160.8	NA
Provence-Alpes-Côte d'Azur	Durance	16648	90.8	52.4	95.4	186.2	143	Italy
	Côtiers Côte D'Azur	13667	99.8	43	95.4	195.2	143	Italy
Nord-Pas de Calais	Escaut	11377	60.7	91.8	99.9	160.6	126	Belgium
	Sambre	1005	91.4	8.1	99.9	191.3	126	Belgium
Lorraine	Moselle - Sarre	15034	97.2	63.7	83.8	181	120.6	Germany
	Meuse	4741	60.2	20.1	83.8	144	120.6	Germany

5. CONCLUSIONS

The development of **Physical Water Accounts (PWAs)** for use in **water- or WEFE nexus CGE models** can follow multiple approaches, depending on data availability and the spatial alignment of the study region. Ideally, PWA data correspond directly to the **exact study region**; however, when such data are not available, **approximative** or **representative regions** can be used as approximation. In cases where no suitable PWA data exist, **data collection** is possible, though it is typically resource-intensive in terms of time, labour, and cost.

In this study, we analyse the PWA availability for **five sites** of the *InnWater* project, which vary in geographic scale, hydrological characteristics, and socio-economic contexts. The sites include **river basins** such as *Seine-Aval, Middle Brenta* and *Middle Tisza*, geographic regions like *West Country*, and **islands** and their river basins including *Corsica* and *La Réunion*. The analysis of extraction data at all sites is limited to **groundwater and surface water**, while usage focused on **agriculture, industrial production,** and **piped water**.

The data for these sites are obtained through a combination of approaches to derive the **PWA area** as the reference region for the PWA data. For some sites, PWA data were retrieved directly from **online databases** matching the study regions. For others, data are collected from **approximative or representative regions** when exact matches were unavailable. In cases where neither exact nor representative data existed, water abstraction and usage data were **aggregated from lower-level sources** such as municipal or catchment-level measurements. The selection of data and the site-specific definition of PWA areas, ensures consistent and comparable datasets across all sites while accommodating differences in data availability and spatial resolution.

When constructing a PWA for a CGE model, the first step is to define a **study region (a PWA area)** that is sufficiently representative of the intended CGE area. Once the CGE region has been established, corresponding PWA data must be obtained. If pre-existing PWA data are unavailable, new data must be collected and compiled. It is important to note that the **assembly of economic data for a regional Social Accounting Matrix (SAM)** may pose greater challenges than compiling the PWA itself. Therefore, the feasibility of developing a water- or WEFE nexus CGE model depends **particularly on access to SAMs or to macroeconomic data suitable to build SAMs**. Ensuring that the chosen CGE region is adequately representative allows for reliable integration of water extraction and usage data into the model, **enabling assessment** of sectoral water dependency and resource allocation.

Thus, to develop **water** or **WEFE nexus CGE models** for river basins (or other **hydrological regions**), the identification of **representative CGE regions** should be prioritised. If compatible economic datasets and PWAs do not exist or cannot be collected at low cost, data acquisition expenses can become substantial and therefore require a careful cost–benefit analysis. **In Europe**, representing hydrological regions that align with **administrative NUTS2 boundaries** appears to be a promising approach, as PWAs are typically available and, regional SAMs may also exist (see García-Rodríguez et al. 2023, 2025). European river basin districts with available PWAs and potential suitability for water CGE modelling can be identified by analysing the overlap between the river basin districts (EEA, 2025 RBD) and the European NUTS2 regions (Eurostat, 2025 b), for which regional SAMs may exist (see García-Rodríguez et al., 2023, 2025).

From a practical perspective, these modelling approaches facilitate **quantitative evaluation of water availability and use** across sectors, providing insights into potential **reallocation strategies under scarcity**, **policy interventions**, and **economic or environmental trade-offs**. By integrating well-structured PWAs with regional SAMs in CGE models, researchers and policymakers can simulate the economic and environmental impacts of water-related policies, including irrigation management, industrial water use, and piped water supply. Ultimately, this framework supports **evidence-based water governance**, contributing to more efficient and sustainable management of freshwater resources within diverse socio-economic and environmental contexts.

Water or WEFE nexus CGE models at the (sub-)river basin level can significantly support water governance objectives at both **European and global scales** by providing economy-wide analyses at spatially customised resolutions. This approach captures the **regional heterogeneity** of river basins and their **complex interlinkages** between the economy and natural resources. Integrating economy-wide analysis with water (or WEFE nexus) aspects enables the examination of **cross-sectoral relationships** and the **"whole-of-society"** perspective emphasised in the **European Water Resilience Strategy (EWRS)** (European Commission, 2025). Moreover, it supports the assessment of impacts related to the **United Nations SDGs** (United Nations, 2015), particularly Clean Water and Sanitation (SDG 6), Responsible Consumption and Production (SDG 12), and Climate Action (SDG 13). Therefore, **combining CGE models and PWAs** for sites with robust data availability represents a promising approach to **advancing evidence-based water governance**.

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