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INN WATER

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

Replication assessment of WEFE nexus CGE models

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EXECUTIVE SUMMARY

Computable General Equilibrium (CGE) models are powerful tools for assessing how economic and environmental changes affect markets, sectors, and households. Extending these models to capture the **Water-Energy-Food-Ecosystems (WEFE) nexus** provides valuable insights for sustainable resource management. While agriculture and energy are typically included in existing models, integrating water and ecosystems requires additional, often specialized, datasets. The feasibility of building WEFE nexus CGE models for river basins depends on **data availability**. Social Accounting Matrices (SAMs), the foundation of CGE models, are usually collected for administrative regions but not for natural units like river basins. Approximations are possible when river basin boundaries align with administrative regions (e.g., NUTS2 regions in Europe), where SAMs already exist. Physical Water Accounts (PWAs) and sectoral data on water, energy, and food are essential for properly representing the WEFE nexus, while ecosystem data remain the most challenging to include. In practice, developing new datasets is possible but requires significant **time, funding, and institutional support**. Thus, assessing data availability is essential for developing WEFE nexus CGE models for river basins.

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ACRONYMS

CGE model	Computable General Equilibrium model
PWA	Physical Water Account
SAM	Social Accounting Matrix
t.b.c	To be confirmed
WEFE nexus	Water, Energy, Food and Ecosystem nexus

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1. INTRODUCTION

Computable General Equilibrium (CGE) models are quantitative economic models that represent the entire economy as a system of interdependent markets, agents, sectors, and production factors. They are commonly used for impact analysis, policy evaluation, and economic assessment. In this way, CGE models help assess the effects of changes in the economy or policy (e.g., changes in prices or taxes), as well as changes related to the environment (e.g., impacts caused by climate change). CGE models exist at the level of world regions, individual countries, and subnational regions.

WEFE nexus CGE models capture the four pillars of the WEFE nexus: W(ater), E(nergy), F(ood), and E(cosystems). Traditionally, CGE models represent economic production through the most important sectors of the economy. In many regional CGE models, agriculture and energy are included as production sectors, thereby covering the F(ood) and E(nergy) pillars. However, representing the W(ater) and E(cosystems) pillars requires specific extensions to the standard CGE framework.

Figure 1 present schematically the frameworks of WEFE nexus and CGE models. In the project InnWater, the WEFE nexus pillar of primary interest is “water”) the blue arrow on the grey background). For the CGE model, water enters the economic system as a production factor (e.g., groundwater or surface water). The production factor water enters production processes directly (e.g., as irrigation water in agriculture) or it is processed before as piped water by the water provider. Piped water is supplied to other industries and households.

The intersectoral linkages between water and the other WEFE nexus pillars are defined by water usage for consumption or production**.** Industries using raw water reduce natural water resources and emit pollutants into the water bodies as ecosystems (the “ecosystem” pillar). Energy is used to produce water and food. However, energy consumption creates emissions to the environment (CO_2 emissions) as linked to the ecosystem pillar. Energy production also requires water, e.g., cooling water. The production of food (i.e., the food pillar) requires water and, at the same time, contributes to the pollution of water bodies as ecosystems (e.g., by the application of fertiliser and pesticides). Finally, raw water is processed as piped water and consumed by households as drinking water. In InnWater, the REWEFE model is developed to analyse the interactions between water use, energy and food production, ecosystems and economic activities on Reunion Island**.**

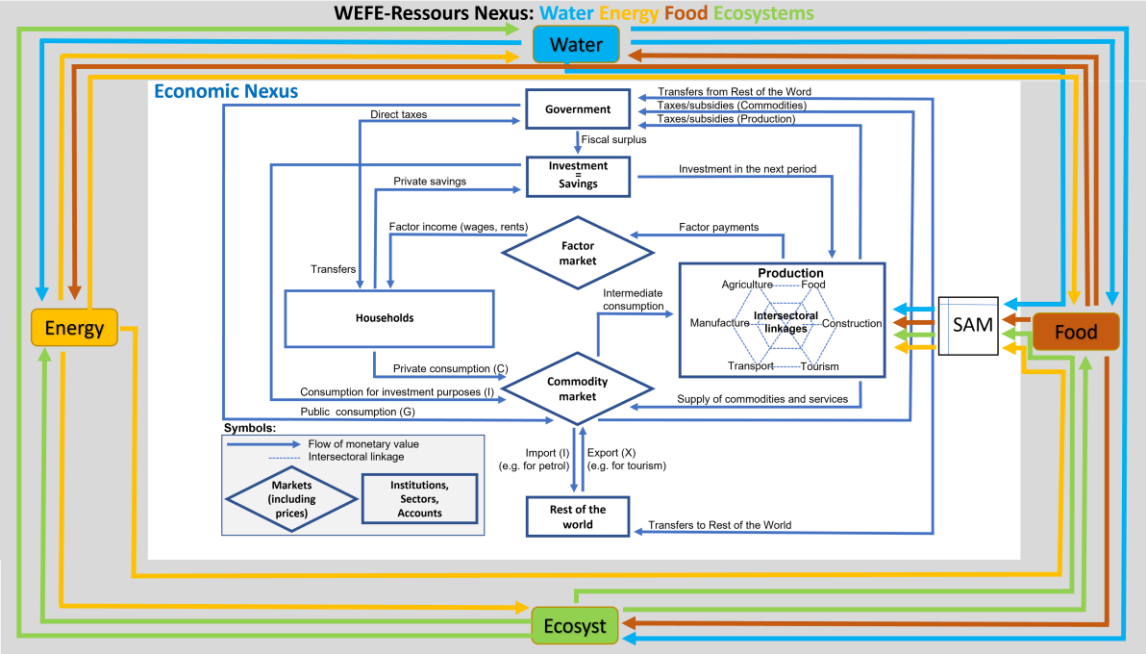

Figure 1: WEFE nexus and CGE model

Note: Graph adapted from Henseler et al. (2022)

CGE models are based on macroeconomic statistical data, typically provided in Social Accounting Matrices (SAMs). The macroeconomic information contained in the model's database determines what can be represented within the CGE model. Representing the WEFE nexus pillars in a CGE model requires the inclusion of corresponding data in the SAM. Building WEFE nexus CGE models for river basins (or other study regions) involves two main challenges: A suitable SAM must be available—either as an existing dataset or constructed from scratch, which requires intensive data collection and labour. The necessary data for representing the WEFE nexus pillars in the SAM must be accessible.

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2. METHODOLOGY

2.1 Social Accounting Matrix to represent River Basins

A **Social Accounting Matrix (SAM)** is an economic data framework that gives a complete picture of all transactions and transfers between different economic agents (households, firms, government, and the rest of the world) over a given period, usually one year.

SAMs are most often built for **administrative regions**, where macroeconomic data are systematically collected. The most common case is at the **national level**, since the necessary statistics—such as input–output tables, national accounts, balance of payments, trade data, treasury data, and household or enterprise surveys—are usually available. In some cases,

regional SAMs also exist at smaller scales, such as departments, counties, municipalities, or cities.

For **natural regions** (like river basins), building a SAM is more challenging because economic statistics are rarely collected for such areas. Natural regions are generally defined for the management of natural resources (such as water) and are based on geographic or geological boundaries (rivers, mountains, forests, climate zones, etc.). Since macroeconomic statistics are not typically needed for resource management, they are usually not available for these regions. However, when the boundaries of one or more administrative regions closely match those of a natural region, a SAM can be used to represent it.

Table 1 shows that, for the CGE pilot and replication sites, the river basins correspond to administrative regions (European NUTS-2 level). For the islands of **La Réunion** and **Corsica**, the river basin boundaries match the administrative borders exactly. In the case of **Seine-Aval**, the administrative region of **Haute-Normandie** (Upper Normandy) provides a good approximation of the river basin.

Table 1: Administrative regions approximating the river basins and availability of SAM

	La Réunion	**Seine-Aval**	**Corse**
Administrative region	La Réunion (NUTS2)	Upper Normandy (NUTS2)	Corse (NUTS2)
Coverage	exact	approximated	exact
SAM available	Yes, provided by the OMEGA project: Croissant et al. (2023)	Yes, provided by the regional model RHOMOLO: García-Rodríguez et al. (2023, 2025)	Yes, provided by the regional model RHOMOLO: García-Rodríguez et al. (2023, 2025)

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2.2 Splitting accounts of existing SAM

In the regional SAMs for the pilot and replication sites **La Réunion**, **Seine-Aval**, and **Corsica**, the **WEFE nexus pillars** are not explicitly represented as separate accounts. **Water (W-pillar)** and **Energy (E-pillar)** are combined into a single account. **Food (F-pillar)** is represented through the agriculture account and is further aggregated within manufacturing (as food processing). **Ecosystems (E-pillar)** are not included in the SAM at all.

Therefore, the regional SAMs need to be **partially disaggregated and extended** in order to properly represent the WEFE nexus pillars (for a detailed example for Réunion Island, see Henseler 2025). Table 2 provides an overview of **the implicit representation of the WEFE nexus** pillars in the regional SAMs.

Table 2: Administrative regions approximating the river basins and availability of SAM

	La Réunion	Seine-Aval	Corse
Water (W-Pillar)	Aggregated in an account with electricity, water supply, sanitations, waste services	Aggregated in an account with mining and quarrying, electricity, water supply, sanitations, waste services; Data sources: García-Rodríguez et al. (2023,2025). Cordier, (2011)	Aggregated in an account with mining and quarrying, electricity, water supply, sanitations, waste services; Data sources: García-Rodríguez et al. (2023,2025), BRGM (2025), DREAL Corse (2025)
Energy (E-Pillar)	Primary energy (petrol) as a commodity, coal aggregated in other industries, electricity aggregated with water supply, sanitations, waste services	Primary energy (petrol, coal aggregated in other manufacturing), electricity aggregated with water supply, sanitations, waste services	Primary energy (petrol, coal aggregated in other manufacturing), electricity aggregated with water supply, sanitations, waste services
Food (F-Pillar)	Agriculture and food processing separate accounts	Agriculture separate accounts, food processing aggregated in manufacturing	Agriculture separate accounts, food processing aggregated in manufacturing
Ecosystems (E-Pillar)	Environmental data not represented in SAM, representation by satellite accounts.	Environmental data not represented in SAM, representation by satellite accounts.	Environmental data not represented in SAM, representation by satellite accounts.

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2.2.1 Water (W-Pillar) in the SAM

Disaggregating water from an aggregate account requires information on the value of water used by different sectors as:

- **a production factor** (e.g., groundwater extracted by water suppliers to produce piped water, or surface water extracted by agriculture for irrigation),
- **an intermediate commodity** (e.g., piped water used by industries), or
- **a final consumption good** (e.g., piped water consumed by households).

In addition to water supply and use, **wastewater treatment services (sanitation)** may also be important for representing the **W-pillar** in a WEFE nexus CGE model.

If statistics on water extraction or consumption are available, these can be used directly to derive values in the SAM. If monetary data are not available, **physical quantities of water** can be converted into monetary values of water extraction and consumption. Such data on extraction and use are provided in **Physical Water Accounts (PWA)**. Beyond serving as a basis for valuation, PWAs can also be used to build a **satellite account** that represents physical water quantities and supports the inclusion of the **ecosystems (E) pillar**. Table 3 presents an overview of the data availability of data to disaggregate the water pillar.

Table 3: Availability of data to represent water in the SAM

	La Réunion	Seine-Aval	Corse
Data on extraction costs and prices	Special reports, see Henseler (2025)	Agence de l'eau Seine-Normandie (2024), Agence de l'eau Seine-Normandie (2025)	Agence de l'eau Rhône-Méditerranée-Corse (2024)
Physical Water Accounts	Special reports, see Henseler (2025)	BNPE (2025), SIDESA (2025), Comité de bassin Seine-Normandie (2025)	BNPE (2025), Comité de bassin de Corse (2025)

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2.2.2 Energy (E-Pillar) in the SAM

Disaggregating electricity from an aggregate account requires information on the value of electricity used by different sectors as an **intermediate commodity**. Similar to the case of water, the value of electricity consumption can be obtained directly as **monetary data** from statistical databases or reports, or it can be derived from the **quantities of electricity consumed**.

The production and consumption of **primary energy sources** (e.g., petroleum, coal, gas) are, in some SAMs, shown separately, while in others they are aggregated into broader accounts. Gas is often grouped together with electricity and water. If other primary energy sources are not represented individually, they may be included within the commodity accounts of other industries. Disaggregating these values requires **detailed information**, which can be drawn from specialized reports and databases.

Table 4: Availability of data to represent energy in the SAM

	La Réunion	Seine-Aval	Corse
Electricity and gas	See Henseler (2025)	INSEE (2024), SDES (2025), Datagouv (2025)	INSEE (2024), SDES (2025), Datagouv (2025)
Primary energy (petrol, coal)	OMEGA SAM (Croissant et al. 2023), see Henseler (2025)	INSEE (2024), SDES (2025), Datagouv (2025)	INSEE (2024), SDES (2025), Datagouv (2025)

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2.2.3 Food (F-Pillar) in the SAM

In most SAMs, **agriculture** is represented as a separate account, sometimes also including **fisheries and forestry**. This account can be considered a representation of **food** in WEFE nexus models. In some cases, the agricultural sector is further **disaggregated into subsectors (e.g., cropping, livestock)**.

Some SAMs also include an aggregate or differentiated **food processing sector**, which can represent the **F-pillar** without further modification. However, if modelling the food processing sector as part of the F-pillar is required and it is not separately represented in the SAM, it can be **disaggregated** from the aggregate account where it is included, using statistics from reports or databases.

Table 5: Availability of data to represent food in the SAM

	La Réunion	Seine-Aval	Corse
Agriculture	In the OMEGA SAM (Croissant et al. 2023), as aggregate sector with fishery and forestry	In the RHOMOLO SAM as aggregate sector with fishery and forestry; Data sources: García-Rodríguez et al. (2023,2025)	In the RHOMOLO SAM as aggregate sector with fishery and forestry, Data sources: García-Rodríguez et al. (2023,2025)
Food processing sectors	In the OMEGA SAM (Croissant et al. 2023), as aggregated sector	Aggregated in RHOMOLO SAM in manufacturing; Disaggregation possible based on data sources: Agreste (2025a), Agreste (2021), Chambres d'agriculture de Normandie (2025), INSEE (2023), French ministry of Agriculture and Food (2025)	Aggregated in RHOMOLO SAM in manufacturing. Disaggregation possible based on following data sources: Agreste (2025b), DRAAF Corse, (2024), DRAAF Corse (2018), INSEE (2022), The French ministry of Agriculture and Food (2025)

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2.2.4 Ecosystems (E-Pillar) in the SAM

In most SAMs, **ecosystems** are not explicitly represented, since they are not usually accounted for in monetary terms. The monetary valuation of ecosystems or environmental services is challenging; however, **environmental economic accounts** provide a framework for including such information in a SAM.

If monetary valuation is not the primary objective, **physical values** can also be used to represent the environmental or ecosystem dimension. These physical values can be included in **satellite accounts** as supplementary information to the SAM. While the SAM itself is consistently based on monetary values, satellite accounts can provide data in other units, externally to the SAM. In

this way, data such as **emissions, water extraction, or water use** can be incorporated into the CGE model database without affecting the internal consistency of the SAM.

Table 6: Availability of data to represent ecosystems and environment in the SAM

	La Réunion	Seine-Aval	Corse
Water quantities (PWA)	Special Reports, for a detailed description see Henseler (2025)	BNPE (2025)	BNPE (2025), Eaufrance — SIE Corse (2023)
Greenhouse gas emissions	Computed emission coefficients, for a detailed description see Henseler (2025)	According to the method described in Henseler (2025)	According to the method described in Henseler (2025)
Water pollutants	Special reports of emissions and from sectors and households; for a detailed description see Henseler (2025)	Agence de l'eau Seine-Normandie. (2019,2022). SIAAP (2023), DREAL Normandie (2025); Office International de l'Eau. (2002), GIP Seine-Aval, 2025; According to the method described in Henseler (2025)	Office de l'Environnement de la Corse (2023), Agence de l'eau Rhône-Méditerranée-Corse. (2024), DREAL Corse (2025), Office International de l'Eau (2002); According to the method described in Henseler (2025)

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3. RESULTS

Table 7 summarises the expected data availability for the **Seine-Aval** and **Corsica river basins**, compared with the **Réunion Island river basin**. The table shows that for Réunion Island, as the pilot site for developing the CGE model, all the required data were available. For the replication sites, macroeconomic data in the form of a **Social Accounting Matrix (SAM)** are available, at least at a **reasonably approximated level**. The WEFE nexus pillars—Water (W), Energy (E), and Food (F)—can be disaggregated in the existing SAM using data available online (in databases, reports, or studies). Although the datasets themselves have not yet been downloaded, their availability is assumed, and additional options for retrieving them are expected once the publishing institutions are contacted.

Data representing the **Ecosystem (E) pillar** are less readily available. Various sources provide information on environmental issues (see Table 6), but for the specific purpose of building a CGE model, requesting data directly from these institutions may be necessary. Often, data on water pollution are provided as point measurements of concentrations, while the **absolute quantities of pollutants** entering the water are not presented. Deriving **aggregated quantity data** for a river basin may therefore require additional computations or specific data requests from the relevant institutions.

Representing the environmental pillar in terms of **economic behaviour or scenarios** within the CGE model may also require targeted data surveys in the corresponding river basins. For the pilot site, La Réunion, a survey was conducted to assess the **value of coral reefs** (e.g., willingness-to-pay as an indicator of the value of specific environmental services). This information can be **incorporated into the CGE model** as scenario inputs or used to derive a monetary value for ecosystem services. For the **Seine-Aval** and **Corsica river basins**, the relevant ecosystem services still need to be identified according to local priorities, and corresponding surveys should be designed and conducted.

Table 7: Overview availability of data

	La Réunion	Seine-Aval	Corse
Macroeconomic data for CGE model calibration (i.e., SAM)	yes	yes	yes
W(ater) pillar	yes	yes	yes
E(nergy) pillar	yes	yes	yes
F(ood) pilar	yes	yes	yes
E(cosystem) pillar	yes	t.b.c.	t.b.c.

4. CONCLUSIONS

The assessment of data availability for constructing a **Social Accounting Matrix (SAM)**, and for extending it to a WEFE nexus SAM following the methodology outlined in Henseler (2025), indicates that the necessary **datasets are accessible for the replication sites Seine-Aval and Corsica**. While the concrete tasks of data acquisition, detailed analysis, and the computation of monetary values and proportional disaggregation within the SAM remain to be undertaken, the present evaluation provides sufficient evidence to affirm the feasibility of developing WEFE nexus CGE models for these sites.

Concerning the development of CGE WEFE nexus models for new river basins (or other regions), we can conclude that the decision to build such a model for a study region **requires an initial assessment of data availability**.

In principle, it is always possible to construct a regional SAM as the database for any region. However, this **can be costly if no SAM already exists** for the study area and a new one must be developed. Building a new SAM requires gathering macroeconomic data, which, if not statistically recorded, would need to be collected through surveys. While in theory macroeconomic data can be surveyed for any region, in practice the **costs may be too high** and ensuring consistent data collection can be challenging.

When evaluating the **feasibility of building a WEFE nexus CGE model** for a river basin (or any other natural region), the availability of data should be carefully checked—for instance, whether a SAM representing the region already exists or whether macroeconomic data are available to construct one. For Europe, regional **SAMs are available at the NUTS2 level** for the base year 2017. These data, published by the European Commission's Joint Research Centre (JRC) (García-Rodríguez et al., 2025,2023), can serve as a starting point for constructing a river basin SAM, as river basin boundaries can often be approximated by aggregating or matching NUTS2 regions.

Furthermore, to represent water extraction and usage, **physical water accounts (PWAs)** need to be available. These are often provided **at the level of administrative regions** (e.g., NUTS2) or for larger hydrological units such as river basins or administrative sub-catchments. The **availability of such data varies by country** and depends on national statistical systems.

Thus, the ideal requirements for building WEFE nexus CGE models are:

- The river basin **approximately corresponds** to the borders of NUTS2 regions for which regional SAMs are available.
- The river basin **corresponds to administrative sub-catchments** for which PWAs are available (i.e., sectoral extraction and usage data).
- The river basin corresponds to regions for which other statistical data representing the WEFE nexus are available.

With these requirements in place, constructing WEFE nexus CGE models for river basins follows the same principles as constructing other regional CGE models: **the feasibility depends on the availability of statistical data** to build the SAM and the model. If new economic data must be collected to create a database for the CGE model, then data availability effectively constrains what can be modelled. However, with **sufficient time, funding, and human resources**, regional SAMs or the necessary statistical datasets can be newly developed for many potential regions of interest.

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