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Modelling the WEFE nexus on Reunion Island

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Abstract

The increasing frequency of extreme weather events, geopolitical conflicts, and environmental pressures underscores the urgent need for sustainable resource management. This study introduces a Computable General Equilibrium model (CGE model) integrating the Water-Energy-Food-Ecosystem nexus for Réunion Island, facing situations of water scarcity, economic vulnerability, and environmental challenges. The model simulates interactions between key resource sectors and can be used to assess impacts of economic shocks, environmental changes and policy measures. Four scenarios highlight the impacts of global shocks, water availability, and policy instruments, such as pricing mechanisms for sewage treatment. The model serves as a macroeconomic laboratory for scenario analysis and policy evaluation. It is suitable to contribute to the sustainable development discussions, aligning with policy objectives, e.g., the United Nations Sustainable Development Goals, the European Green Deal and the recently released European Water Resilience Strategy.

Key words: Réunion Island, WEFE nexus, CGE model, policy scenarios, impact assessment, water governance,

JEL-code: C68, Q25

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1 Introduction

Droughts occur worldwide, even in regions that have not traditionally faced water scarcity. The increasing frequency of floods leads to the destruction of infrastructure and land. Both droughts and floods result in harvest losses and food shortages. Geopolitical conflicts, such as the Russian invasion of Ukraine, cause trade distortions in food and energy markets, leading to rising prices on energy and food markets. At the same time, the climate change, growing environmental pressures, ecosystem degradation, and biodiversity loss emphasise for sustainable and environmentally friendly transitions (European Environment Agency, 2024; United Nations, 2024; Guy Carpenter, 2024; Toreti et al., 2023). Since 2000, the global community has faced significant challenges driven by human activities. Counteracting measures are required to ensure economic growth and equity (World Bank, 2023a). These objectives are reflected in 10 out of the 17 United Nations Sustainable Development Goals (SDG) to be achieved by 2030 (United Nations, 2025). At the European level, the Green Deal and the European Climate Pact outline strategic components for the sustainable use of natural resources and the reduction of environmental pressures (European Commission, 2025a, b). Policymakers, researchers, and society must work together to understand and mitigate the effects of these multiple crises, which include economic recessions, political and military conflicts, and financial constraints.

The Water-Energy-Food-Ecosystem (WEFE) nexus framework provides a holistic approach to analysing the interconnections between key resource sectors: water, energy, food, and ecosystems (Hoff, 2011; Pueppke, 2021). Understanding these interlinkages within economic systems is essential for sustainable resource management and governance, ensuring that environmental, economic, and social boundaries are respected (Schlemm et al., 2024). Computable General Equilibrium (CGE) models serve as macroeconomic tools to analyse economic systems and their responses to changing conditions (Böhringer and Löschel, 2006). For more than three decades, CGE models have been used in economic research on water management and, more recently, on WEFE nexus research (Bardazzi and Bosello, 2021). These models allow for the simulation and assessment of environmental and economic scenarios, policy measures, and investment strategies.

This study presents the REWEFE model, a CGE model that simulates the interactions between the WEFE nexus pillars in the French overseas region of Réunion Island. The REWEFE model enables a comprehensive analysis of resource management, economic development, environmental sustainability, and societal impacts in Réunion Island.

Réunion Island, a volcanic island in the western Indian Ocean near Madagascar, lies approximately 2,000 km from mainland Mozambique. In 2021, 36% of the island's population lived below the metropolitan poverty line, a significantly higher rate than mainland France (15%). Additionally, 19% of the working-age population was unemployed, far exceeding the national French average of 7.3% in 2023 (INSEE, 2024). Réunion Island exemplifies the challenges of managing the WEFE nexus in an economically viable manner, particularly in water governance. Despite its tropical climate and seasonal rainfall (November to April), rainfall distribution is highly uneven. While the eastern part of the island receives more than 3,000 to 4,000 mm of annual rainfall, the western part experiences significantly lower precipitation, with less than 2,000 mm per year and even less than 1,000 mm along the west coast (Leroux et al., 2023), see Figure 1a.

Most of Réunion Island's population resides along the narrow coastal strip, where economic activities are concentrated in the southwest, near the port and tourism infrastructure (INSEE, 2024). Water supply is managed by local providers, but leakage from distribution infrastructure results in approximately 40% water loss. Investments are needed to repair pipelines and reduce waste. Additionally, the current water pricing system does not incentivise household water saving behaviour (Marchal, 2024). A reform in water governance could help reduce water waste while ensuring affordability for lower-income households. The severe drought of 2024/2025, which reduced water reserves by 22%, underscores the island's vulnerability to water scarcity and the need for improved water management strategies (ReutilisationEau.fr, 2025). Réunion faces issues with the environmental impacts of wastewater management. More than 50% of households are not connected to collective wastewater treatment systems and rely on autonomous sewage disposal, contributing to nitrogen and phosphorus pollution in water bodies. Addressing these environmental challenges requires investment in wastewater treatment infrastructure.

The sugar industry in Réunion requires substantial irrigation, particularly in the drier western regions, see Figure 1b. While the island aims to increase food and energy self-sufficiency (Nuwer, 2023), sugarcane cultivation dominates agricultural production, limiting land availability for food crops and contributing to pollution. As a result, Réunion relies heavily on food imports, making it vulnerable to global market fluctuations (Nuwer, 2023). The agro-food system illustrates how specialisation and market dependence contribute to structural fragility. Achieving food self-sufficiency would require systemic transformations, including diversifying agricultural production and reducing dependence on sugarcane cultivation (Billen et al., 2024). Agricultural activities, particularly sugar production, also contribute to aquatic pollution through pesticide and fertiliser runoff, threatening biodiversity, e.g., for the coral reefs (see Figure 1d). These environmental risks are particularly concerning for the tourism industry, a crucial sector that employs 4.9% of the workforce and is a major source of income (INSEE, 2025).

Energy production is another critical issue for Réunion's self-sufficiency goals. Currently, thermal electricity production relies on imported fossil fuels, contributing to CO_2 emissions. Alternative energy sources include biomass, wind, solar, and hydroelectric power, all of which are interconnected with the WEFE nexus (see Figure 1c) (Selosse et al., 2018).

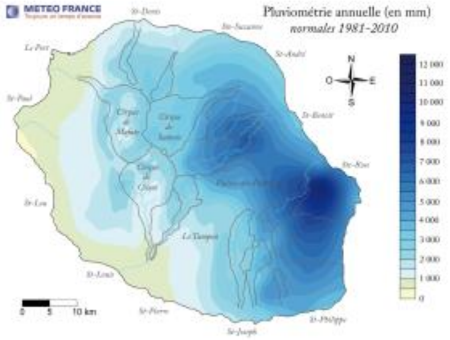

Figure 1a: Cumulated annual mean precipitation in mm in 1981 – 2010. Source: Leroux et al. (2023: 73)

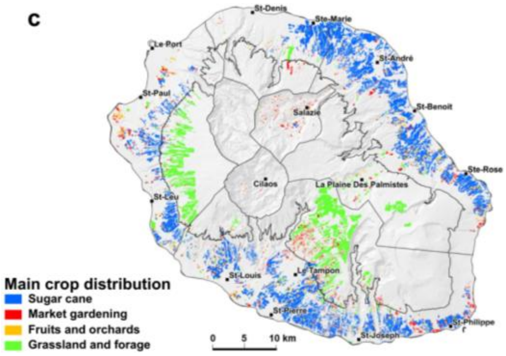

Figure 1b: Main crop distribution over the period 2018–2020, from the analysis of RPG data (Registre Parcellaire Graphique, 2021). Source: Billen et al. (2024: 58)

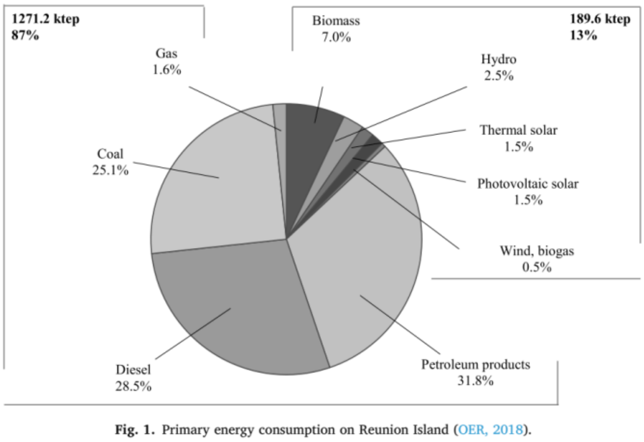

Figure 1c: Primary energy consumption in Reunion Island. Source: Garabedian et al. (2020: 4)

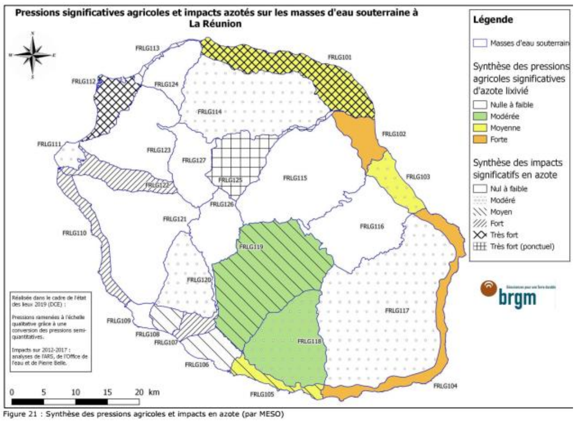

Figure 1d: Environmental pressure caused by agricultural production in Reunion Island. Source: Office de L'Eau (2019e: 48)

The island's environmental and policy objectives, coupled with its water governance and energy transition challenges, make a WEFE nexus CGE model a valuable tool for scenario analysis and policy assessment. In this paper, we present the first CGE model to integrate the four WEFE nexus pillars—water, energy, food, and ecosystems—for Réunion Island. Concretely, we (i) extend the PEP-1-1 standard model (Decaluwé et al., 2013) by incorporating water as piped water and production factor, sanitation services and multiple electricity production activities. We (ii) design and simulate economic scenarios that address key research questions relevant to Réunion Island's sustainable development. And (iii) we interpret the results of these scenarios, which can feed the policy discussion on Réunion Island's path of sustainable development.

2 Methodology

2.1 Literature on CGE models in WEFE nexus research

The application of computable general equilibrium (CGE) models in water and WEFE (Water-Energy-Food-Ecosystems) nexus research has been widely examined in academic literature. A review of existing studies indicates a growing number of publications over time, alongside a broadening of research questions (Table 1). Johannson (2005) provides an early review of CGE models applied to water research, particularly focusing on the valuation of irrigation water. He identifies five CGE studies between Berck et al.'s pioneering work in 1990 and 2002. Dudu and Chumi (2008) extend Johannson's review by analysing CGE models as analysis tools for irrigation water management, identifying approximately 20 studies published between 2000 and 2007. Dinar (2014) further expands the scope by examining CGE models in the context of water and policy interventions, moving beyond agricultural applications to include water use by competing sectors and economic agents. Dinar (2014) builds on the review by Dudu and Chumi (2008), identifying 49 papers published between 2000 and 2011.

Calzadilla et al. (2016) review 30 studies spanning the period from 1991 to 2016. They classify CGE models based on whether water is treated explicitly or implicitly as a production factor and analyse varying degrees of substitutability between water and other primary production factors. Bardazzi and Bosello (2021) conduct a systematic review of CGE studies with a focus on water-related and WEF nexus research questions. They identify 46 studies published between 2000 and 2021 that examine the water-food relationship, of which 25 explicitly model water as a production factor and 21 do so implicitly. Additionally, they identify 11 studies that incorporate the water-energy relationship, with four modelling water explicitly and seven implicitly. More recently, Castelli et al. (2024) review 27 articles from 2000 to 2021, finding that 12 studies explicitly represent water. Among these, five focus on the water-food nexus, three on the water-energy nexus, three examine water without a specific WEFE nexus linkage, and only one study considers the water-energy-food linkage. The increasing number of reviews of CGE model on water or WEFE nexus topics indicate a growing interest for CGE models as a method.

Table 1 provides an overview of the number of studies analysed by selected review studies. The table indicates the WEFE nexus pillars covered, illustrating a growing use of CGE models for analysing water and WEFE nexus-related research questions over time. The increasing number of CGE model applications in water and WEFE nexus research underscores their relevance as analytical tools for studying these interdependencies. Research questions exploring water-food linkages are well represented in the literature, whereas studies examining water-energy relationships are less frequent. Furthermore, CGE studies incorporating three or all four WEFE pillars remain underrepresented. Castelli et al. (2024) identify only one study that explicitly simulates the “WEF nexus”, and they do not find any CGE studies that comprehensively represent all four WEFE pillars. Moreover, within macroeconomic modelling frameworks, socioeconomic dimensions are often not explicitly considered due to the aggregated nature of CGE models. Recently, Henseler et al. (2025) analysed 157 journal articles with focus on CGE models considering water, including the WEFE nexus topics. Their analysis reveals a wide range of research scopes and applications of water-focused CGE models, yet highlights an underrepresentation of studies that address all four pillars of the WEFE nexus. In particular, the ecosystem and environmental dimensions are notably underrepresented in WEFE nexus CGE studies.

Table 1: Studies presenting literature reviews on CGE model and WEFE nexus research

Study	Period	WEFE Nexus Pillar	Number of studies
Johannson (2005)	1991-2002	W	5
Dudu and Chumi (2008)	2000-2007	W	7
Dinar (2014)	2000-2011	W	49
Calzadilla et al. (2016)	1991-2016	W	30
Bardazzi and Boselo (2021)	2000-2021	WE, WF	67
Castelli et al. (2024)	2000-2021	W, WE, WF, WEF	12
Henseler et al. (2025)	1991-2025	W, WE, WF, WEF, WEFE	157

2.2 Framework of the WEFE nexus CGE model

CGE models represent the economic system as a circular nexus, where monetary values are exchanged and transformed. In contrast, the WEFE nexus operates as a biophysical resource nexus, governed by material flows and ecosystem dynamics. Integrating CGE models into WEFE nexus research requires bridging the economic nexus, expressed in monetary terms, with the biophysical nexus of water, energy, food, and ecosystems. Social Accounting Matrices (SAMs) serve as data base of CGE models and typically include specific WEFE nexus pillars. Thus, CGE models can represent these pillars as activities, factors, or commodities. Commonly, SAMs include agricultural and food processing activities (for the "F(ood)" pillar) and energy production and consumption (for the "E(nergy)" pillar). Within a CGE framework, these activities interact with other sectors and economic agents. However, linking CGE models with WEFE nexus pillars not captured in the SAM framework requires embedding WEFE nexus data additionally into the SAM.

Figure 2 illustrates the CGE model as an economic nexus embedded within the broader WEFE resource nexus (shaded in grey). The biophysical resource flows of the WEFE nexus feed into the SAM, which then transmits this information into the CGE model. Within the CGE model, activities and economic agents exchange monetary values through markets and transfers (represented by blue arrows on a white background). Water enters the economic system as a production factor, sourced from groundwater or surface water (Figure 3). It is either used directly in production—such as irrigation in agriculture—or processed into piped water by utility providers before being supplied to industries and households.

The intersectoral linkages between water and other WEFE nexus pillars are defined by its role in consumption and production processes. Industrial water usage depletes natural resources and generates pollutants, impacting the ecosystem (i.e., the "(E)cosystems" pillar). Energy production relies on water, for instance, in cooling processes, while energy consumption contributes to environmental degradation through CO_2 emissions. Similarly, food production depends on water inputs while also affecting water quality through fertilisers and pesticide runoff. Finally, raw water undergoes treatment before being supplied as drinking water to households. Within the WEFE nexus framework, CGE models are particularly well-suited to analysing the interdependencies between water use, energy production, and economic activities, offering valuable insights into resource allocation and sustainability challenges.

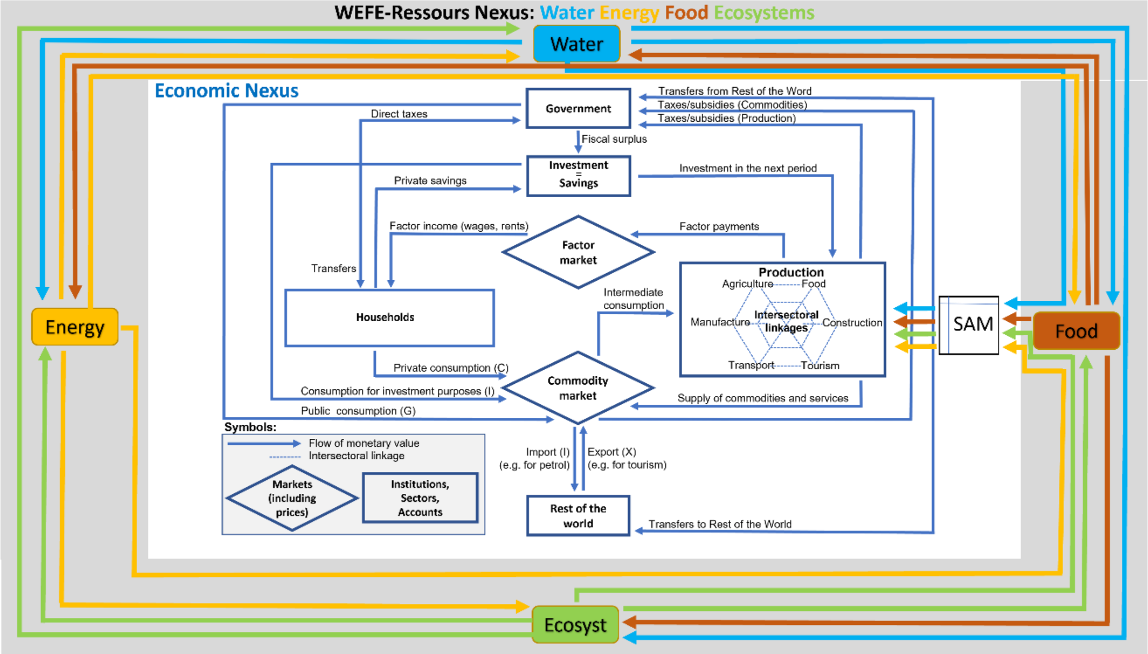

Figure 2: WEFE nexus and CGE model. Source: adapted from Henseler et al. (2022)

Figure 3 illustrates the WEFE nexus pillars for Réunion Island by depicting the proportion of water extraction and usage. On the left, the extracted raw water—categorised as groundwater and surface water—represents the W(ater) pillar, denoted by "(W)." Nearly 75% of this raw water is processed into piped water, though nearly 40% is lost during distribution. The remaining 60% is consumed by households and industries, establishing indirect linkages between the water (W), energy (E), and food (F) pillars, denoted as "(W)," "(E)," and "(F)," respectively.

Industrial use of both raw and piped water connects the water pillar to the food pillar (F), particularly in the production of sugar, beverages, and bottled water, as well as to the energy pillar, where water is used in electricity production for cooling. Additionally, raw water extraction for irrigation and the use of piped water for livestock feeding further link the water pillar to the food pillar. Agriculture accounts for nearly a quarter of total raw water extraction, primarily from surface water sources, for irrigation.

The interaction between water usage and raw water extraction also contributes to the (E)cosystems pillar , here depicted as "(Ec)". Water withdrawals impact ecosystem water availability, while household and industrial water use results in pollutant emissions. Wastewater discharge from households and industries, as well as fertiliser and pesticide runoff from agricultural activities, contribute to raw water pollution. However, this linkage between water use and pollution is not explicitly represented in Figure 3.

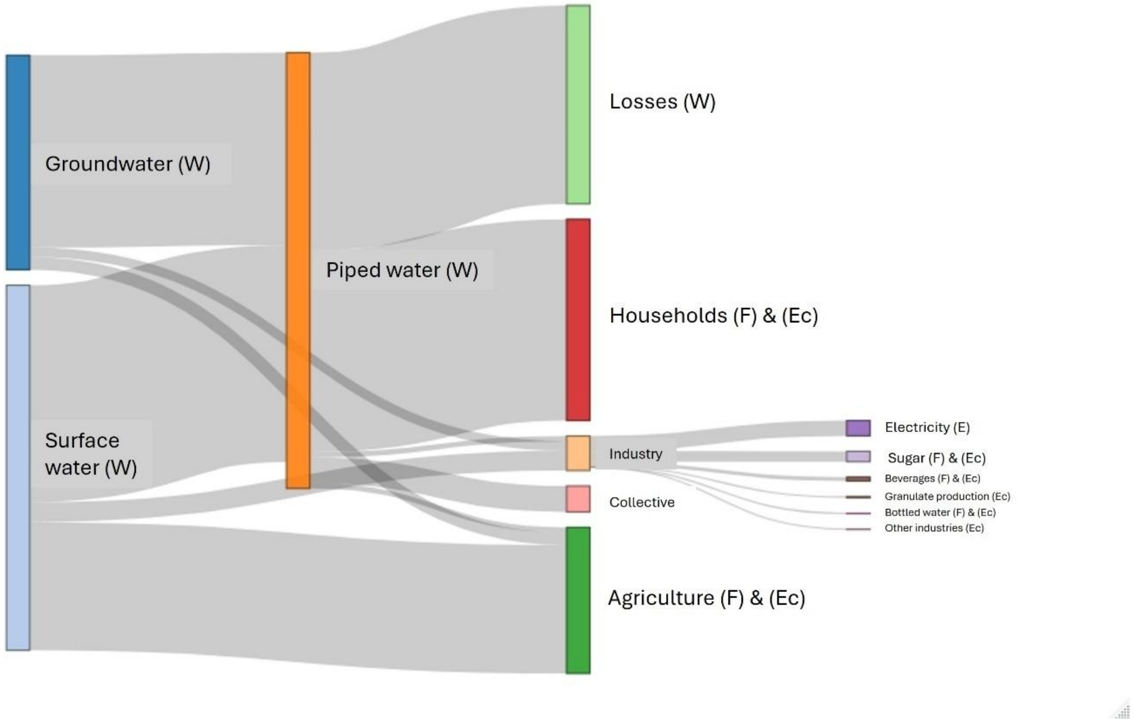

Figure 3: Water extraction and usage as Sankey chart. Source: Own presentation, based on Office de l'eau (2019a), Office de l'eau (2022).

Notes: (W) = WEFE nexus water pillar; (E) = WEFE nexus energy pillar; (F) = WEFE nexus food pillar; (Ec) = WEFE nexus ecosystems pillar.

2.3 The Social Accounting Matrix (SAM)

We calibrate the REWEFE model using an extended version of an existing Social Accounting Matrix (SAM) for the base year 2016 (Croissant et al., 2023). Table 2 provides an overview of the original SAM for Réunion Island and details the disaggregated activities, commodities, and production factors incorporated into the extended version. In refining the SAM, we introduce greater sectoral detail by disaggregating the original accounts. Specifically, we include a new energy commodity, three water and sanitation services, one waste service activity, and three electricity-producing activities. Additionally, we refine the classification of production factors by subdividing capital into groundwater and surface water capital (representing raw water as a production factor) and non-water capital. This disaggregation is based on various regional data sources on Réunion Island’s water supply and usage, (e.g., IREEDD, 2019; Office de l’Eau, 2019a-h; Office de l’Eau, 2022).

Table 2: Extension of the original SAM

	Original SAM	**Extension**
Activities/Commodities	Agriculture (agri)	Electricity energy (elec) [b]
	Food (food)	Renewable energy (elhy) [a]
	Other industry (oind)	Biomass energy (elbi) [a]
	Petrol (petr) [b]	Fossil fuel energy (elpe) [a]
	Construction (cons)	Water, sanitary and waste services (wasa) [a]
	Transport (tran)	Piped water distribution (wadi) [b]
	Public services (admi)	Collective sanitary service (saco) [b]
	Financial services (sefi)	Non-collective sanitary service (sanc) [b]
	Non-financial services (senf)	Waste services (wast) [b]
Production factors	Labour (flabo)	Non-water capital (fcanw)
	Capital	Groundwater capital (fgwa)
		Surface water capital (fswa)
Taxes, subsidies and margins	8	8
Agents	Households (hous)	
	Government (gove)	
	Rest of the World (rowe)	

Notes: [a] only as activity, [b] only as commodity,

To incorporate the ecosystem pillar of the WEFE nexus, we extend the SAM with satellite accounts that capture environmental externalities, including water pollutants, CO_2 emissions, and physical flows of different water types. Table 3 presents these environmental satellite accounts, listing the environmental indicators alongside their associated economic activities and institutional agents (e.g., households). In the agricultural sector, production processes contribute to water pollution through the release of active ingredients from plant protection products and nitrogen from fertiliser application, while simultaneously extracting groundwater and surface water for irrigation. The industrial sector, particularly the sugar and rum industry, similarly contributes to nitrogen emissions and raw water extraction. The transport sector emits heavy metals, while also consuming water for piped water production. Households play a dual role in the WEFE nexus, both emitting pollutants through domestic water use and consuming piped water, which in turn generates wastewater. Beyond water-related emissions, both industrial activities and households contribute to CO_2 emissions, primarily through the combustion of petroleum-based fossil fuels.[1]

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[1] For a comprehensive description of data sources, processing methodologies, and the construction of the extended SAM and environmental satellite accounts, see Henseler (2025).

Table 3: Emission and physical water flows in the CGE model

		Agriculture	**Industry**	**Services**	**Households**
Emissions	Active substances and other micro pollutants (27)	Pesticides application			
	Heavy metals (8)			Transport	
	Nitrogen	Agricultural production	Sugar and rum industry		Water usage
	Phosphorous		Sugar and rum industry		Water usage
	Oxygen demand and suspended solids (3)		Sugar and rum industry		Water usage
	CO_2 emissions	Petrol usage	Electricity production, petrol usage	Transport	Petrol usage
Physical flow	Surface water	Extraction for irrigation	Extraction for industrial usage	Extraction for water supply	
	Ground water	Extraction for irrigation	Extraction for industrial usage	Extraction for water supply	
	Piped Water	Usage of piped water			Usage of piped water
	Wastewater				Supply of wastewater

As the standard model for a single-country comparative static analysis, we adopt the PEP single-country static model (PEP-1-1), as described in Decaluwé et al. (2013). The PEP-1-1 model has been widely applied in economic research, covering a broad spectrum of topics, including research questions related to WEFE nexus topics. For an overview of various applications of the PEP standard models to WEFE nexus research topics, see Table A-1 in Appendix.

To capture the WEFE nexus within a Computable General Equilibrium (CGE) framework, we extend the PEP-1-1 model by incorporating additional activities and commodities, as detailed in Table 2. The REWEFE model explicitly represents the water, sanitation, and waste sector, which produces four key commodities and services: piped water, collective wastewater treatment services, non-collective sewage discharge and waste management services. In the model, water and sanitation services require raw water (groundwater and surface water) as a production factor to supply piped water. Additionally, the agricultural sector and industrial sectors utilise raw water as an input for production.

Regarding the energy representation, the model distinguishes between primary and secondary energy sources. Petroleum is modelled as a primary energy commodity, used for both intermediate and final consumption. Electricity production is disaggregated into three distinct activities, each relying on different primary energy sources: fossil fuel-based electricity generation (using petroleum and coal), biomass-based electricity production and utilising biomass from agri-food production as fuel and renewable energy generation, including wind, hydro, and solar power. Electricity is consumed both as an intermediate input in production and as final consumption by households. Notably, the biomass-based electricity sector establishes a direct link between the energy and food pillars of the WEFE nexus, as it relies on agricultural by-products (e.g., molasses from sugar production).

2.4 Specification of the production function

A key aspect of integrating the WEFE nexus into a Computable General Equilibrium (CGE) model is the specification of the production function. Figure 4 illustrates the standard PEP-1-1 production tree, where water and electricity enter production as both intermediate inputs and factors of production. In this framework, raw water—distinguished as groundwater (W_1) and surface water (W_2)—is treated as a form of capital and combined with non-water capital into a composite capital-water (KW). Additionally, piped water (W_3) is consumed as an intermediate input, alongside energy commodities such as electricity and petroleum.

A significant limitation of this standard formulation is the assumption that groundwater, surface water, and non-water capital are substitutable. This implies that a shortage of non-water capital (machinery, land, or livestock) can be offset by increased use of groundwater or surface water, and vice versa, with equal flexibility. While some degree of substitution between groundwater and surface water is reasonable, the idea that capital and water can replace each other at the same rate is not technically plausible. While technological advancements—such as piped water infrastructure or water-saving technologies increasing productivity or reducing overall water demand—can influence water use, water itself cannot be replaced by capital or labour as a fundamental production factor.

To address this issue, we restructure the production function, as shown in Figure 5. The new specification preserves the Leontief structure for intermediate inputs, ensuring that their proportions remain fixed in production. For the primary production factors, however, a different approach is introduced. Instead of grouping water and capital together, labour and non-water capital are combined into a labour-capital composite (LK), while groundwater and surface water are aggregated into a raw water composite (WC). This allows for substitution between different water sources without allowing water to replace capital or vice versa. The labour-capital composite and the raw water composite are then combined into a labour-capital-water bundle (LKW), where substitution between these components is significantly restricted. By assigning a low elasticity of substitution between the labour-capital composite and the raw water composite, the new specification prevents implausible substitutions between capital and water, while still maintaining flexibility where it is technically justified. This refinement ensures a more realistic production tree, reflecting the fundamental differences between physical capital, labour, and natural water resources in the economic system.

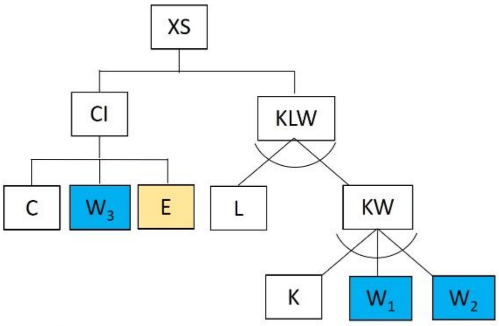

Figure 4: Production tree with water and energy in the PEP 1-1 standard model.

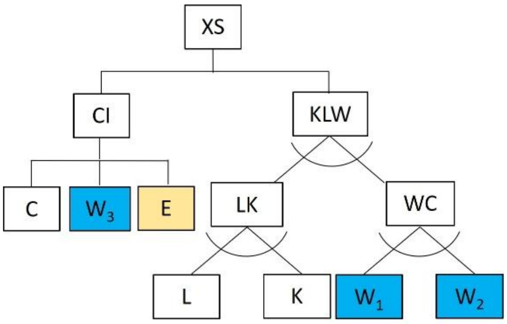

Figure 5: Production tree with water and energy in the specified REWEFE model

Notes:
C = other intermediate commodities as input;
CI = intermediate consumption;
E = Energy as intermediate commodity (e.g., electricity)
K = capital (K) as single production factor or as composite of different capital types;
KW = as capital composite with capital (K) and water (W) as natural capital production factor;
KLW = value added resulting from labour (L) and capital (K) and water (W);L = labour (L) as primary production factor or as composite of different labour types;
LK = value added resulting from labour (L) and capital (K); LK(W) = value added resulting from labour (L) and capital (K) with water

(W) included implicitly as a natural capital;
W_1 = raw water type 1 as a production factor (e.g., groundwater);
W_2 = raw water type 2 as a production factor (e.g., surface water);
W_3 = water as intermediate commodity (e.g., piped water);
WC = raw water composite as a production factor;
XS = output of production;

The Equations 1 to 11.2 presents the specification of the REWEFE model in algebraic notation. Equation 1 and 2 represent the first two levels of the production tree combining the value added (VA) of the primary production factors (KLW) and intermediate demand (CI) to output (XS). Equation 9 represents the intermediate demand by the activities. The three equations follow a Leontief functional form. To model the composition of value added, Equations (3) and (4) define the aggregation of labour, capital, and water into a composite production factor (KLW) using a CES (constant elasticity of substitution) functional form. Within this structure, Equations (5) and (6) describe the substitution possibilities between different labour types and the corresponding demand across activities.[2]

The treatment of capital is further refined. Equations (7) and (8) distinguish between water-related capital and non-water capital, ensuring that substitution occurs only where technically justified. Equation (3a) represents in Figure 5the second and third levels of the production structure, integrating raw water (WC) with non-water factors (LK). The substitution between different raw water types (groundwater W_1 and surface water W_2) and their sectoral allocation is formalised in Equations (3.1) and (3.2). The computation of industry value added takes into account both capital and water-related costs. Equation (3.4) determines the value added generated from labour and capital, while Equation (4) specifies the demand for non-water capital by different sectors. Finally, Equations (11.1) and (11.2) calculate the price of industry value added, incorporating the prices and quantities of non-water capital (*PNWAT*, *NWAT*) and water (*PWAT*, *WAT*), as well as the broader capital composite.[3]

Value added demand in industry *j* (Leontief)

$$VA_j = v_j XST_j \qquad \textit{Eq. 1}$$

Total intermediate consumption demand in industry *j* (Leontief)

$$CI_j = io_j XST_j \qquad \textit{Eq. 2}$$

CES between of composite water and non-water factors

$$VA_j = B_j^{VA} \left[\beta_j^{VA} WAT_j^{-\rho_j^{VA}} + \left(1 - \beta_j^{VA}\right) NWAT_j^{-\rho_j^{VA}} \right]^{-\frac{1}{\rho_j^{VA}}} \qquad \textit{Eq. 3a}$$

Relative demand for composite water and non-water factors by industry *j* (CES)

$$WAT_j = \left\{ \left[\frac{\beta_j^{VA}}{\left(1 - \beta_j^{VA}\right)} \right] \left[\frac{PNWAT_j}{PWAT_j} \right] \right\}^{\sigma_j^{VA}} NWAT_j \qquad \textit{Eq. 3.1}$$

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[2] However, in the REWEFE model, only a single category of labour is considered.

[3] The complete algebraic formulation of the REWEFE model and a detailed comparison of the model extensions relative to the PEP-1-1 framework can be found in Henseler (2025).

Demand for composite water by industry *j* (CES)

$$WAT_j = B_j^{WAT_{mult}} \times B_j^{WAT} \left[\sum_{k_{wat}} \beta_j^{WAT} KD_{k_{wat},j}^{-\sigma_j^{KD}} \right]^{-1/\sigma_j^{KD}} \qquad \textit{Eq. 3.2}$$

Demand for water type (*k_wat*) by industry *j* (CES)

$$KD_{k_{wat},j} = \left[\frac{\beta_j^{WAT} PWAT_j}{RTI_{k_{wat},j}} \right]^{\sigma_j^{KD}} B_j^{WAT\left(\sigma_j^{KD}-1\right)} WAT_j \qquad \textit{Eq. 3.3}$$

CES between of composite labour and non-water capital

$$\begin{aligned} NWAT_j = B_j^{NWAT} \Big[& \beta_j^{NWAT} LDC_j^{-\rho_j^{NWAT}} \\ & + \left(1 - \beta_j^{NWAT}\right) KDC_j^{-\rho_j^{NWAT}} \Big]^{-1/\rho_j^{NWAT}} \end{aligned} \qquad \textit{Eq. 3.4}$$

Relative demand for composite labour and capital by industry *j* (CES)

$$LDC_j = \left\{ \left[\frac{\beta_j^{NWAT}}{\left(1 - \beta_j^{NWAT}\right)} \right] \left[\frac{RC_J}{WC_J} \right] \right\}^{\sigma_j^{NWAT}} KDC_j \qquad \textit{Eq 4a}$$

CES between labour categories

$$LDC_j = B_j^{LD} \left[\sum_{l} \beta_j^{LD} LD_{l,j}^{-\sigma_j^{LD}} \right]^{-1/\sigma_j^{LD}} \qquad \textit{Eq. 5a}$$

Demand for type *l* labour by industry *j* (CES)

$$LD_{l,j} = \left[\frac{\beta_j^{LD} WC_j}{WTI_{l,j}} \right]^{\sigma_j^{LD}} B_j^{LD\left(\sigma_j^{LD}-1\right)} LDC_j \qquad \textit{Eq 6a}$$

CES between non-water capital categories

$$KDC_j = B_j^{KD} \left[\sum_{k_{nwat}} \beta_j^{KD} KD_{k_{nwat},j}^{-\sigma_j^{KD}} \right]^{-1/\sigma_j^{KD}} \qquad \textit{Eq. 7}$$

Demand for non-water capital by industry *j* (CES)

$$KD_{k_{nwat},j} = \left[\frac{\beta_{k_{nwat},j}^{KD} \; RC_j}{RTI_{k_{nwat},j}} \right]^{\sigma_j^{KD}} B_j^{KD\left(\sigma_j^{KD}-1\right)} KDC_j \qquad \textit{Eq. 8}$$

Intermediate consumption of commodity *i* by industry *j* (Leontief)

$$DI_{i,j,} = aij_{i,j} CI_j \qquad \textit{Eq. 9}$$

Industry *j* unit cost

$$PP_j XST_j = PVA_j VA_j + PCI_j CI_j \qquad \textit{Eq. 10}$$

Price of industry *j* value added

$$PVA_j VA_j = PWAT_j WAT_j + PNWAT_j NWAT_j \qquad \textit{Eq.11.1}$$

$$PNWAT_j NWAT_j = WC_j LDC_j + RC_j KDC_j \qquad \textit{Eq. 11.2}$$

With

VA_j: Value added of industry j

v_j: Coefficient (Leontief - value added)

XST_j: Total aggregate output of industry j

CI_j: Total intermediate consumption of industry j

io_j: Coefficient (Leontief - intermediate consumption)

LDC_j: Industry j demand for composite labour

KDC_j: Industry j demand for composite capital

B_j^{VA}: Scale parameter (CES - value added)

β_j^{VA}: Share parameter (CES - value added)

ρ_j^{VA}: Elasticity parameter (CES - value added)

ρ_j^{NWAT}: Elasticity parameter (CES - composite non-water capital)

RC_j: Rental rate of industry j composite capital

$LD_{l,j}$: Demand for type l labour by industry j

WC_j: Wage rate of industry j composite labour

$WTI_{l,j}$: Wage rate paid by industry j for type l labour including payroll taxes

β_j^{LD}: Share parameter (CES - composite labour)

σ_j^{LD}: Elasticity (CES - composite labour)

B_j^{LD}: Scale parameter (CES - composite labour)

B_j^{KD}: Scale parameter (CES - composite capital)

B_j^{WAT}: Scale parameter (CES - value added water composite)

$B_j^{WAT_{mult}}$: Multiplier to modify scale parameter (CES - value added water composite)

B_j^{NWAT}: Scale parameter (CES - value added non-water composite)

$\beta_{k,j}^{KD}$: Share parameter (CES - composite capital)

β_j^{WAT}: Share parameter (CES - composite capital: water)

β_j^{NWAT}: Share parameter (CES - composite non water capital)

σ_j^{KD}: Elasticity (CES - composite capital)

σ_j^{NWAT}: Elasticity (CES - composite non-water capital)

$KD_{k,j}$: Demand for type k capital by industry j

KDwat,j: Demand for type water by industry j

WATj: Industry j demand for composite water (i.e., WC: water composite)

NWATj: Industry j demand for composite non water factors (i.e., composite LK: labour and capital)

$RTI_{k,j}$: Rental rate paid by industry j for type k capital including capital taxes

$DI_{i,j}$: Intermediate consumption of commodity i by industry j

$aij_{i,j}$: Input-output coefficient

PP_j: Industry j unit cost including taxes directly related to the use of capital and labour but excluding other taxes on production

PNWATj: Rate of industry j composite non water capital (i.e., composite LK: labour and capital)

PWATj: Rate of industry j composite water (i.e., composite WC: ground and surface water)

PCI_j: Intermediate consumption price index of industry j

PVA_j: Price of industry j value added (including taxes on production directly related to the use of capital and labour)

In contrast to the standard PEP-1-1 model, where full employment is assumed, the REWEFE model introduces a labour market specification that accounts for unemployment. In Réunion Island, the unemployment rate remains high, reaching nearly 20% (INSEE, 2024). This implies that the available labour supply exceeds labour demand in the reference scenario.

Consequently, when labour demand rises in a simulation, it can be served by unemployed individuals re-entering the workforce. To reflect this labour market mechanism, the model adopts a wage curve approach, following Blanchflower and Oswald (1995), where wages and unemployment rates exhibit a negative relationship. This means that as unemployment increases, wage rates tend to decline. Furthermore, labour is assumed to be mobile across sectors, while capital remains sector-specific, ensuring a realistic differentiation in factor mobility.

2.5 Macroeconomic closure

The macroeconomic closure of the REWEFE model follows several key assumptions. World prices are treated as exogenous, following the small-country assumption, which implies that Réunion Island does not influence global market prices. Household minimum consumption levels remain fixed, meaning that basic consumption patterns do not adjust in response to economic changes. The current account balance and changes in inventories are also held constant, preventing adjustments through external borrowing or stock variations. In terms of fiscal policy, government spending is assumed to be fixed, maintaining a stable public expenditure structure. Tax rates remain at their baseline levels, ensuring that fiscal policy does not serve as an adjustment mechanism. Similarly, labour and capital supplies are held constant. In scenario simulations, exogenously fixed variables are explicitly modified, e.g., world market prices, factor supplies, or tax rates are altered. Finally, the exchange rate is fixed at a value of 1, serving as the numeraire of the model. This means that all price variations are measured relative to the exchange rate, ensuring a consistent reference for price adjustments throughout the simulation process.

3 Scenarios

We employ the REWEFE model to simulate scenarios addressing research questions of significance to researchers and policymakers. These scenarios focus on key areas of the WEFE nexus. In the "Water Scarcity" scenario, we model a situation of reduced water availability on Réunion Island. Specifically, the availability of both ground and surface water is decreased by 5%. This scenario assumes that variations in precipitation result in lower levels of water replenishment in both ground and surface water bodies. To simulate this reduction, we shock the model by decreasing the supply of natural capital—namely, ground and surface water—as essential production factors. The 5% reduction aligns with a medium scenario based on Leroux et al. (2023), who forecast precipitation anomalies of -1.81% and -7.23% for optimistic and pessimistic scenarios, respectively.[4]

The "Reduced Leakage" scenario simulates a reduction in water losses due to leakage in the piped water distribution system. Currently, approximately 40% of piped water is lost during distribution. We assume that some of these losses are mitigated through infrastructure repairs, which result in more of the produced water reaching consumers. To simulate this, we shock the model by increasing the productivity of both ground and surface water by 0.5%. The reduction in water loss is an arbitrary assumption, and we do not incorporate the associated infrastructure repair costs, which would require empirical data to model accurately, potentially as increased government spending.

In the "Sewage Disposal" scenario, we model a shift in household wastewater discharge from non-collective to collective sewage systems. Non-collective (or autonomous) sewage disposal systems result in higher pollutant emissions compared to collective systems. By encouraging

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[4] Leroux et al. (2023) provide data on spatial anomalies of precipitation. The computation of the global values can be found in Henseler (2025).

households to transition to collective systems, we reduce the overall emission of pollutants. This is simulated by increasing the tariff for non-collective sewage disposal by 5% while simultaneously decreasing the tariff for collective sewage disposal by 5%. The tariff adjustment is intended to incentivise households to adopt collective systems. However, we do not account for the infrastructure costs involved in connecting households currently using autonomous systems to the collective network.

The "Oil Price Increase" scenario simulates a 5% increase in world crude oil prices. Such an increase affects the economy broadly, particularly sectors that rely on petroleum for production and households consuming petroleum for private transport. This scenario highlights the interconnectedness within the WEFE nexus, demonstrating the linkages between energy and other sectors such as water, food, and ecosystems. The increase in crude oil prices represents a global price shock, which is a frequent occurrence in the real world, sometimes with even more severe impacts, as evidenced by events like the Russia-Ukraine war, started in 2022.

4 Results

4.1 Macroeconomic impacts

Figure 6 presents the changes in macroeconomic indicators across the simulated scenarios, expressed as percentage changes compared to the base year. The largest decrease in gross domestic product (GDP) by 0.3% is observed in the "Oil Price Increase" scenario. As an importer of petrol, Réunion Island is heavily influenced by developments in world oil prices. Rising global prices increase the production costs across industries that rely on petrol as primary energy source for sectors (e.g., transportation) or on petrol-based electricity. Consequently, the economy suffers, with negative effects on production in petrol-dependent sectors. Furthermore, households reduce petrol demand for private transport and electricity, resulting in lower consumption of these commodities. This, in turn, leads to a reduction in overall household consumption by approximately 0.2%.

Decreased household consumption reduces demand for commodities, leading to a decrease in production, intermediate demand, and value added by 0.15%, 0.2%, and 0.1%, respectively. Lower production also results in reduced labour demand and an increase in unemployment by 0.8 percentage points. As a result, workers lose jobs, leading to a reduction in household incomes and a weakened private consumption. The reduced demand for production factors (e.g., petrol) and final consumption commodities leads to a decline in imports by 0.3%. Similarly, exports decrease by 0.2%. In summary, the increase in world crude oil prices results in an overall negative impact on the economy, with a decrease in GDP.

While the "Oil Price Increase" scenario generates significant impacts across activities, markets, and households, the "Sewage Disposal" scenario involves a reallocation effect, with the tariff for non-collective sewage disposal increasing and the tariff for collective wastewater treatment decreasing. This price adjustment incentivises households to shift from more polluting, more expensive autonomous disposal systems to less polluting, collective disposal systems. However, the government's expenditure on subsidising the tariff reduction for collective disposal leads to a net loss in government income, which decreases by nearly 0.1%. Nevertheless, the overall impacts of this policy are neutral to slightly positive: GDP, production, and exports see modest increases, while the unemployment rate decreases. This effect occurs because the government injects money into the economy, though the reduction in government income, caused by a reduce volume of fees for collective water disposal. The loss of the income from collective water disposal limits public spending (e.g., on public services).

While the "Sewage Disposal" and "Oil Price Increase" scenarios affect international trade and tariffs, the "Water Scarcity" and "Reduced Leakage" scenarios primarily impact the production side by causing changes in factor scarcity and productivity. These shocks lead to marginal changes that are difficult to identify at the macroeconomic level. In the "Water Scarcity" scenario, the availability of ground and surface water decreases by 5%, while in the "Reduced Leakage" scenario, the productivity of both factors increases by 0.5%. These opposing shocks lead to different outcomes: the "Water Scarcity" scenario reduces the supply of water, increasing its price as a production factor. In contrast, the "Reduced Leakage" scenario decreases the need for raw water to produce and distribute piped water, resulting in a decline in the price of raw water. While "Water Scarcity" tends to negatively affect the economy, the "Reduced Leakage" scenario has a positive economic impact by improving the productivity of raw water.

The relatively small impacts observed from the "Water Scarcity" and "Reduced Leakage" shocks can be attributed to the limited role that ground- and surface water play as production factors in the economy. These factors contribute only a small share to the overall value added, particularly in sectors where water is a key input. As a result, the overall economic impacts are limited. Additionally, the impact of the "Piped Water" commodity is weak, as water for intermediate and final consumption is not highly significant in the economy. Thus, while these shocks affect specific sectors, the broader economic impacts are minimal, and a more detailed analysis at the sectoral level is required to understand the full effects.

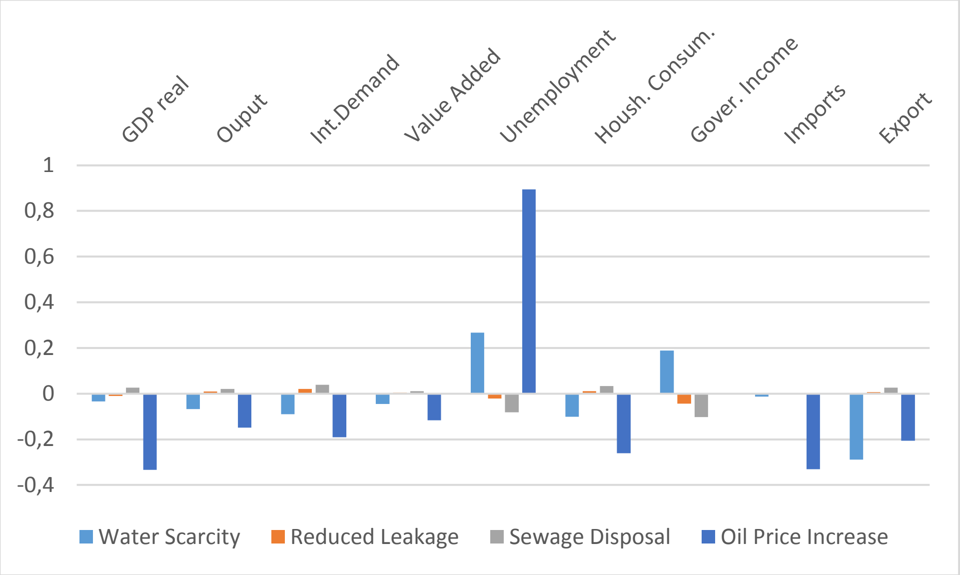

Figure 6: Impact on macroeconomic indicators in %-change from the base

Notes: GDP real = gross domestic product real (in value); Ouptut = production (in value); Int.Demand = Intermediate Demand; Housh. Consum. = final consumption (in value); Gover. Income = government income (in value).

4.2 Production and consumption

Figure 7 illustrates the impacts of the scenarios on production across sectors; Figure 8 shows the impacts on the final consumption by households. In the "Oil Price Increase" scenario, activities that depend on petrol, such as thermic electricity production and transportation, experience significant output reductions. These reductions stem from increased production costs, higher consumer prices, and reduced demand from both industries (as intermediate commodities) and households (as final consumption goods). Figure 8 shows that, in the "Oil Price Increase" scenario, household demand for transport and petrol decreases, as these commodities become more expensive. An intersectoral impact is also observed, as the energy-intensive sectors such as water and wastewater services are affected by rising petrol prices, leading to reduced output in these activities.

In the "Sewage Disposal" scenario, the tariff policy promoting a shift from non-collective to collective wastewater treatment increases output in the sanitary sector, which requires electricity for production. As a result, electricity-producing activities see an increase in output (see Figure 7). Figure 8 shows that households decrease their consumption of non-collective sewage disposal services and increase their consumption of collective wastewater treatment services.

In the "Reduced Leakage" scenario, the increased productivity of raw water stimulates output in the water services sector. With fewer raw water inputs, the sector can produce more piped water. However, the intersectoral impacts are limited, and the marginal decrease in consumer prices for piped water does not lead to significant increases in demand. The low price of piped water, coupled with existing over-consumption, limits the effect on overall production (Figure 6).

In the "Water Scarcity" scenario, the reduction in raw water availability impacts the output of water-dependent sectors such as agriculture, food production, and electricity generation. These effects illustrate the interconnectedness of water with food (via agriculture and food industries) and energy (via electricity production) (Figure 7). However, the impact on household consumption is minimal, as reduced domestic supply is compensated by imports, allowing consumption of food and agricultural products to remain stable (Figure 8).

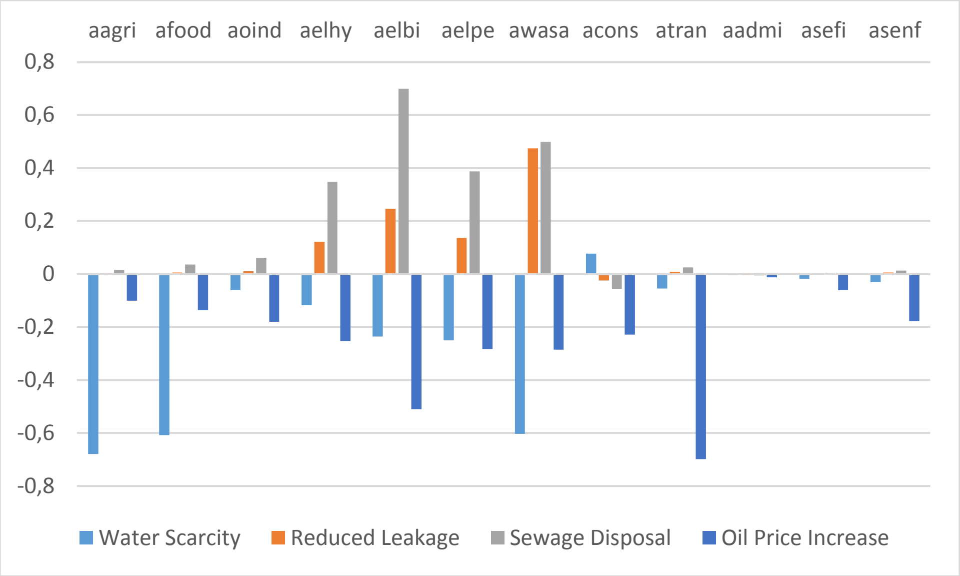

Figure 7: Impact on activities production in %-change from the base

Notes: aagri = agricultural production (including fishery and forestry); afood = food processing industries (including beverages); aoind = other industries; aelhy = electricity production based on renewable energies (hydro power, wind and solar); aelbi = electricity production based on biomass energy; aelpe = electricity production based on fossil fuel energy (petrol and coal); awasa = water, sanitary and waste sector; acons = construction sector; atran = transport sector; aadmi = public services and administration; asefi = financial services; asenf = not financial services (e.g., tourism or trade).

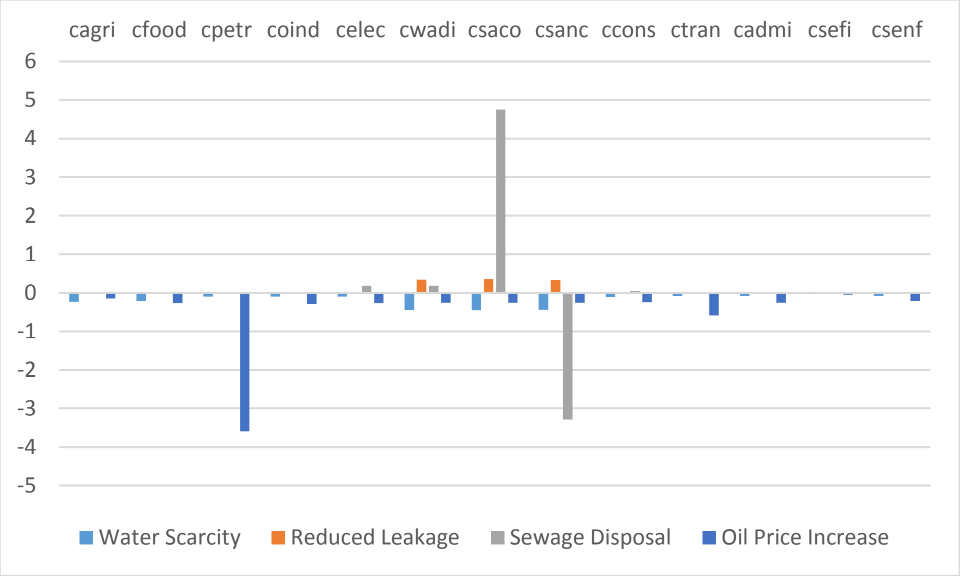

Figure 8: Impact on household consumption in %-change from the base

Notes: cagri = agricultural commodities (including commodities from fishery and forestry); cfood = processed food and beverages; cpetr = petroleum and petroleum products; aoind = commodities from other activities (including coal); celec = electricity; cwadi = distribution of piped water; csaco = collective sanitary service; csanc = non-collective sanitary service; ccons = construction service; ctran = transport service; cadmi = public services and administration; csefi = financial services (e.g., insurance, banking); csenf = non-financial services (e.g., tourism, trade).

4.3 International trade

Figure 9 and 10 present the scenario impacts on import and exports. The "Oil Price Increase" scenario generates the most significant changes in international trade. Petrol imports decrease by 1.5%, and other affected sectors reduce imports to compensate for economic losses caused by higher production costs. Similarly, exports decline due to reduced output (e.g., in the strongly affected transport sector).

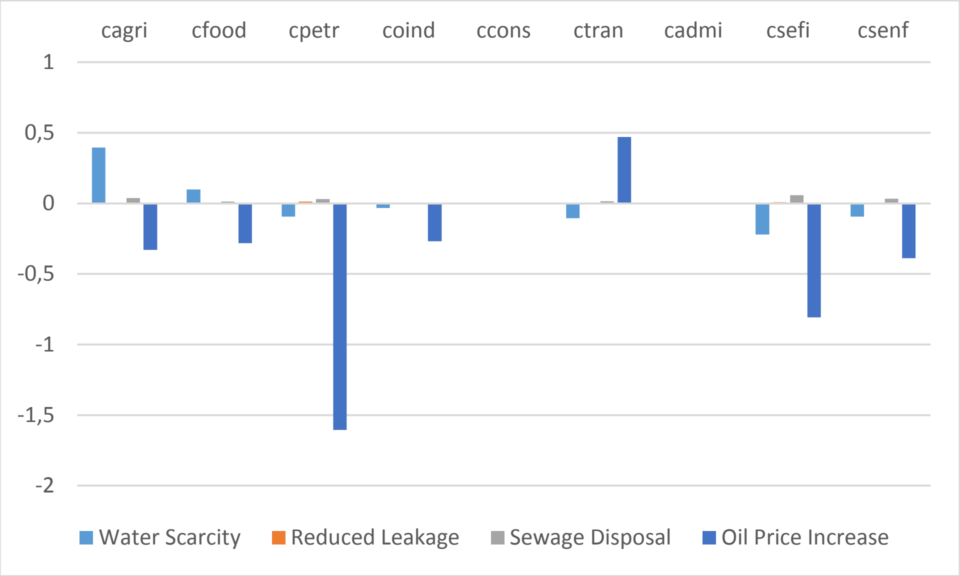

Figure 9: Impact on imports in %-change from the base

Notes: cagri = agricultural commodities (including commodities from fishery and forestry); cfood = processed food and beverages; cpetr = petroleum and petroleum products; aoind = commodities from other activities (including coal); celec = electricity; cwadi = distribution of piped water; csaco = collective sanitary service; csanc = non-collective sanitary service; ccons = construction service; ctran = transport service; cadmi = public services and administration; csefi = financial services (e.g., insurance, banking); csenf = non-financial services (e.g., tourism, trade).

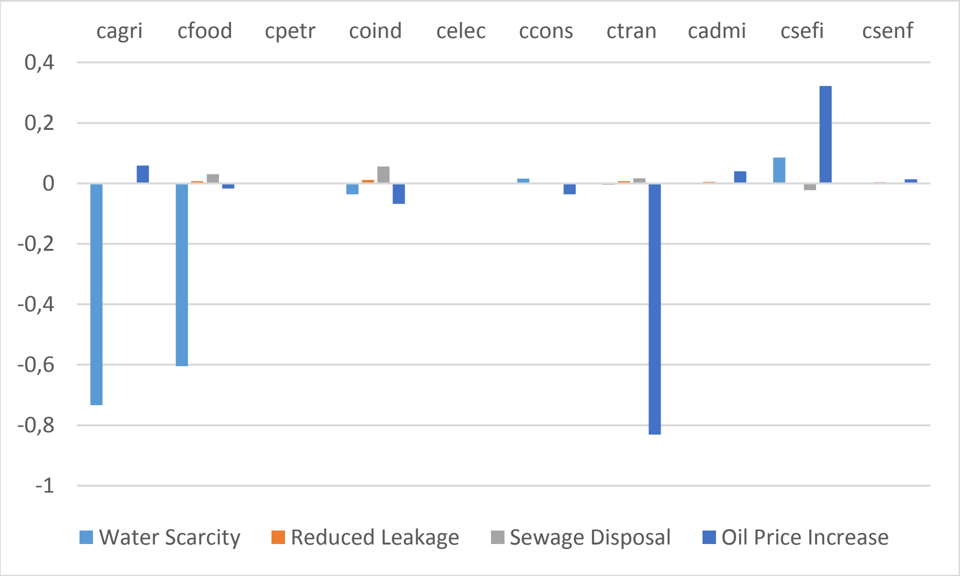

Figure 10: Impact on exports in %-change from the base

Notes: cagri = agricultural commodities (including commodities from fishery and forestry); cfood = processed food and beverages; cpetr = petroleum and petroleum products; aoind = commodities from other activities (including coal); celec = electricity; cwadi = distribution of piped water; csaco = collective sanitary service; csanc = non-collective sanitary service; ccons = construction service; ctran = transport service; cadmi = public services and administration; csefi = financial services (e.g., insurance, banking); csenf = non-financial services (e.g., tourism, trade).

In contrast, the "Reduced Leakage" and "Sewage Disposal" scenarios show only marginal changes in international trade (less than 0.1%), as the impacted services are non-tradable commodities. The "Water Scarcity" scenario leads to an increase in the import of agricultural and food commodities, partially explaining why household consumption remains unaffected. Additionally, exports of agricultural and food products decrease by 0.7% and 0.8%, respectively. This shift in trade patterns helps meet domestic demand through increased imports and reduced exports.

4.4 Consumer and factor prices

Figure 11 shows the change in consumer prices; Figures 12 to 14 present the changes in capital rental rate, reflecting the values of production factor capital. In the "Oil Price Increase" scenario, the price of imported petrol increases by 5%, which is directly reflected in higher consumer prices. However, the price transmission to related commodities, such as transport services, is relatively weak, indicating that supply and demand adjustments occur elsewhere in the economy. In terms of production and consumption changes, output in the transport sector and household consumption decrease, leading to a devaluation of non-water capital in the affected sectors (Figure 12).

In the "Sewage Disposal" scenario, the tariff adjustment for non-collective sewage disposal (sanc) increases the price of non-collective services, while the tariff for collective sewage disposal (saco) decreases, resulting in corresponding changes in consumer prices (Figure 11). This shift leads to a positive net impact on the sector, with increased output in the sanitary sector (Figure 7).

The "Reduced Leakage" scenario results in a marginal decrease in the price of piped water due to increased factor productivity. While this makes piped water cheaper, there is little additional demand for it, as households are already consuming more water than economically efficient. Consequently, the impacts on consumption and production are minimal.

In the "Water Scarcity" scenario, the reduction in raw water resources leads to slight increases in commodity prices for sectors reliant on raw water. However, the impact on household consumption is negligible, as increased imports or decreased exports fill domestic supply gaps

(Figure 9 and 10). Additionally, the value of non-water capital decreases due to reduced production in impacted sectors. The scarcity of raw water increases its capital rent for ground- and surface water, signalling its increased value as a production factor, particularly in water-dependent sectors (Figures 13 and 14). In these sectors, factor costs for water increase substantially—ranging between 40% and 60%—which results in a comparatively stronger decline in production relative to sectors that are not dependent on water as a production factor (see Figure 7). Nevertheless, with production decreasing by less than 1%, the overall effect remains limited. This weak transmission from factor price increases to output can be attributed to the relatively small proportion of production costs accounted for by water. Despite the considerable rise in water costs, their minimal share in total production costs implies that even substantial increases exert only marginal effects on production.

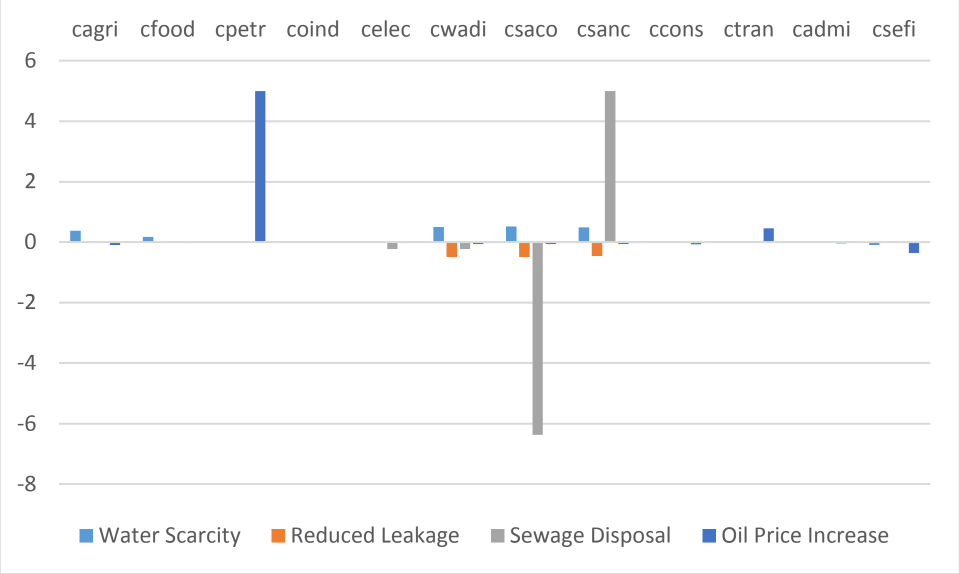

Figure 11: Impact on consumer prices in %-change from the base

Notes: cagri = agricultural commodities (including commodities from fishery and forestry); cfood = processed food and beverages; cpetr = petroleum and petroleum products; aoind = commodities from other activities (including coal); celec = electricity; cwadi = distribution of piped water; csaco = collective sanitary service; csanc = non-collective sanitary service; ccons = construction service; ctran = transport service; cadmi = public services and administration; csefi = financial services (e.g., insurance, banking); csenf = non-financial services (e.g., tourism, trade).

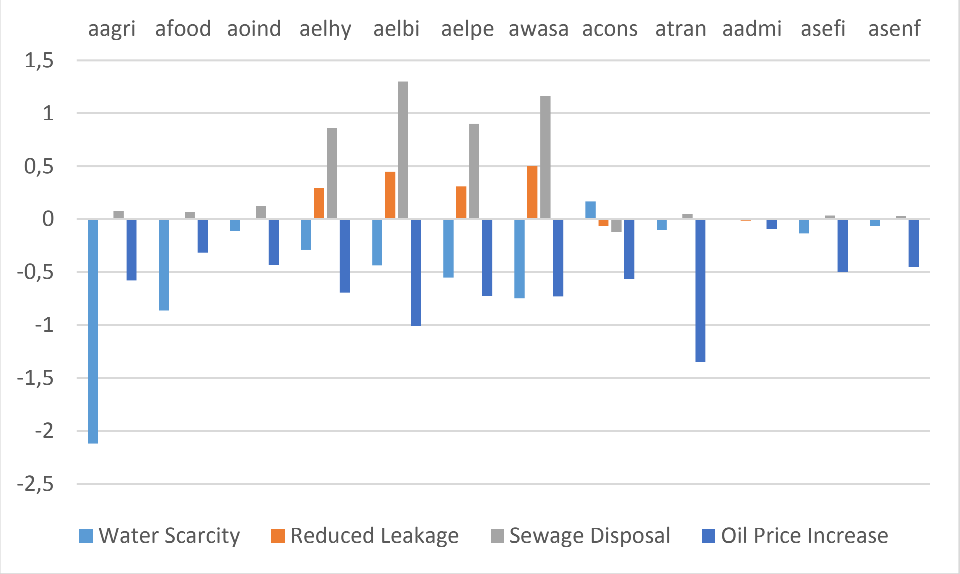

Figure 12: Impact on factor prices for non-water capital in %-change from the base

Notes: aagri = agricultural production (including fishery and forestry); afood = food processing industries (including beverages); aoind = other industries; aelhy = electricity production based on renewable energies (hydro power, wind and solar); aelbi = electricity production based on biomass energy; aelpe = electricity production based on fossil fuel energy (petrol and coal); awasa = water, sanitary and waste sector; acons = construction sector; atran = transport sector; aadmi = public services and administration; asefi = financial services; asenf

= not financial services (e.g., tourism or trade).

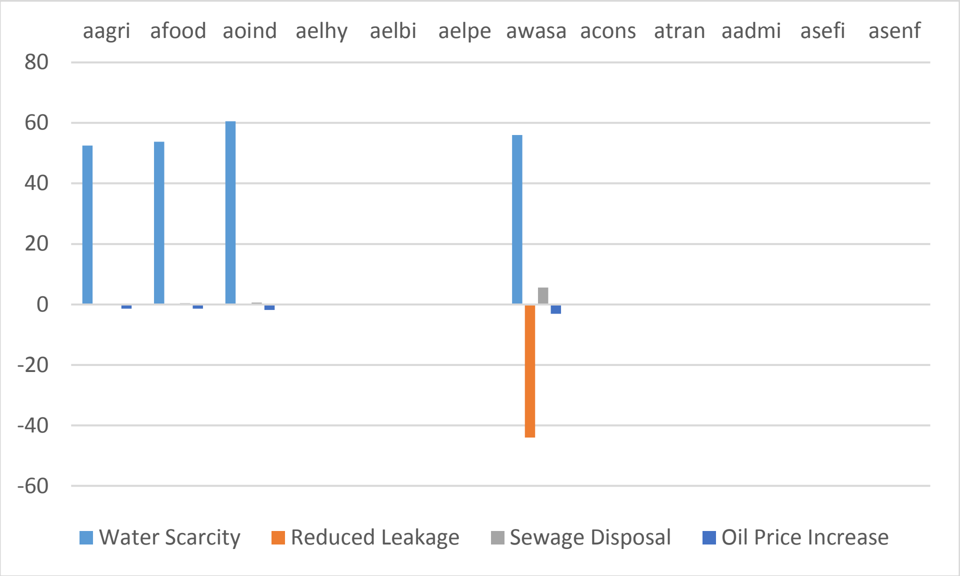

Figure 13: Impact on factor price for groundwater in %-change from the base

Notes: aagri = agricultural production (including fishery and forestry); afood = food processing industries (including beverages); aoind = other industries; aelhy = electricity production based on renewable energies (hydro power, wind and solar); aelbi = electricity production based on biomass energy; aelpe = electricity production based on fossil fuel energy (petrol and coal); awasa = water, sanitary and waste sector; acons = construction sector; atran = transport sector; aadmi = public services and administration; asefi = financial services; asenf = not financial services (e.g., tourism or trade).

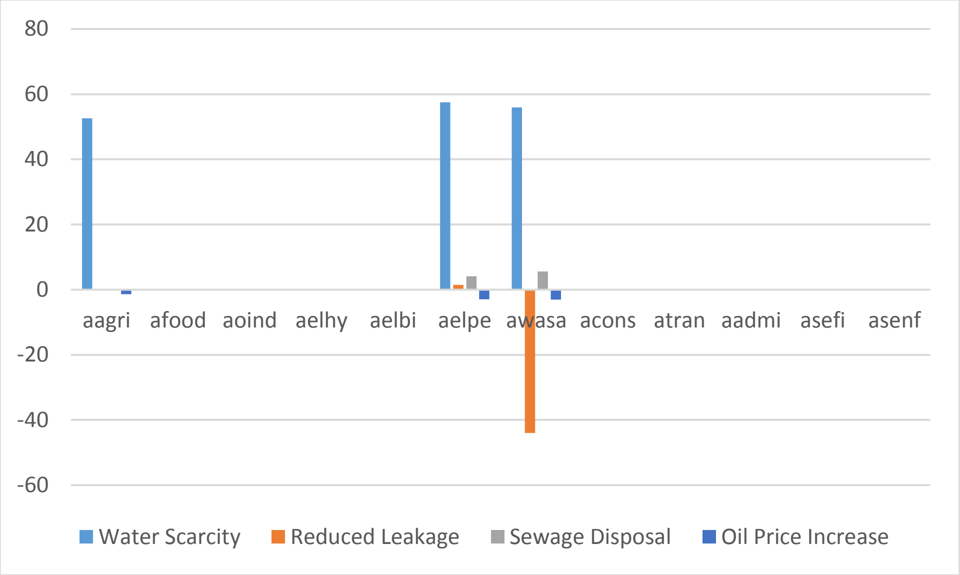

Figure 14: Impact on factor prices of surface water in %-change from the base

Notes: aagri = agricultural production (including fishery and forestry); afood = food processing industries (including beverages); aoind = other industries; aelhy = electricity production based on renewable energies (hydro power, wind and solar); aelbi = electricity production based on biomass energy; aelpe = electricity production based on fossil fuel energy (petrol and coal); awasa = water, sanitary and waste sector; acons = construction sector; atran = transport sector; aadmi = public services and administration; asefi = financial services; asenf = not financial services (e.g., tourism or trade).

4.5 Environmental pollution

Figure 15 shows the environmental impacts of the simulated scenarios. In the "Oil Price Increase" scenario, rising petrol prices impact all sectors, leading to a decrease in CO_2 emissions as production across industries contracts. Also, the reduction of final petrol consumption (Figure 8) contributes to the decrease in CO_2 emissions from petrol. The "Reduced Leakage" scenario shows limited environmental impacts, with reduced emissions due to increased production and consumption stimulated by lower water prices. The "Sewage Disposal" scenario generates positive environmental outcomes by reducing pollutant emissions from non-collective sewage discharge and replacing them with cleaner collective treatment. Nitrogen and phosphorous emissions decrease by 2% and 3%, respectively, as more households shift to collective wastewater treatment. Finally, the "Water Scarcity" scenario leads to a slight reduction in emissions, particularly agricultural nitrogen emissions, due to reduced agricultural activity and fertilisation.

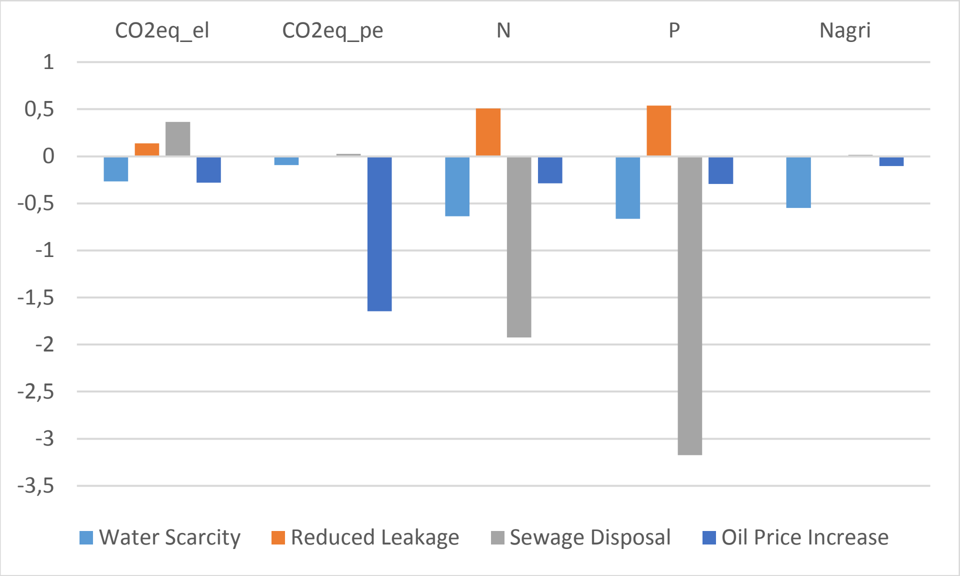

Figure 15: Impact on environmental indicators in %-change from the base

Notes: CO2eq_el = CO2 emissions from electricity producion, CO2eq_pe = CO2 emissions from petrol usage, N = nitrogen emissions from households and industry, P = phosphor, Nagri = nitrogen emissions from agriculture.

5 Conclusions

The French study region, Réunion Island, located in the western Indian Ocean, faces significant challenges related to water governance, particularly within the context of the WEFE (Water, Energy, Food, and Ecosystem) nexus. While the region benefits from annual rainfall, the water supply is subject to seasonal fluctuations and regional scarcity. Private water usage is often inefficient, and the island experiences considerable water losses due to leaks, compounded by the high irrigation demands of sugarcane production. This creates competition for water resources. Additionally, the high number of households using autonomous wastewater disposal systems, and intensive agricultural production pollute the aquatic ecosystems, such as coastal coral reef systems.

Addressing these challenges, includes reducing water losses and minimising pollution, which requires the implementation of effective policy measures. These measures must not only meet the intended policy objectives but also respect the interconnectedness of the WEFE nexus, balancing the challenges of the four pillars—Water, Energy, Food, and Ecosystems. Moreover, water and environmental policies must avoid negatively impacting the societal context, which is characterised by relatively high poverty levels and unemployment rates in the population. Policies that fail to align with the WEFE nexus and socioeconomic objectives are likely to face resistance from the population, making implementation more difficult.

Ex-ante assessments of economic scenarios and policy measures can provide valuable insights for researchers and policymakers regarding the expected impacts. Computable General Equilibrium (CGE) models can serve as ex-ante simulation tools for macroeconomic policy analysis, considering the economy, society, and the WEFE nexus simultaneously. The Réunion Island WEFE nexus CGE model (i.e., the REWEFE model) is as a macroeconomic analysis tool that captures the interdependencies between the four WEFE nexus pillars. The results of four scenarios show the negative economic impacts of petrol prices as global economic shock. Improvement of water infrastructure have minor effects on the broader economy but show positive trends. Additionally, price instruments can encourage a shift from polluting autonomous sewage disposal systems to more sustainable collective sewage disposal systems.

Certain caveats associated with the CGE modelling approach must be considered. The model's behaviour is strongly influenced by the historical data embedded in the social accounting matrix, making the results relatively static and unable to account for future changes in scenarios. CGE models operate at an aggregated, representative level and do not capture the behaviour of individual economic agents. Furthermore, the model's economic behaviour is based on microeconomic theory and optimisation principles, which may not always align with actual economic behaviour. Nevertheless, these limitations are well recognised for CGE models. The ability of CGE model to provide a holistic simulation of the macroeconomy and the WEFE nexus outweighs these drawbacks, which should be considered when interpreting the results. Further testing, validation, revisions and extensions of the REWEFE model are needed. The model can thus serve as a macroeconomic laboratory for simulating scenarios based on empirical and expert knowledge for Réunion Island.

In future research, scenarios can be made empirically based, e.g., by incorporating improved hydrological data. Simulations of improved infrastructure for water distribution or wastewater disposal can consider the costs of repairing water pipes and potential funding options. Furthermore, water tariffs can be simulated, generating funds for policy measures. The environmental indicators, currently implemented as satellite accounts, could be represented endogenously within the model. Furthermore, in the spirit of extending the WEFE nexus concept to include aspects of health, the analytical framework could be expanded into a "WEFE-H" model (e.g., Nuwayhid and Mohtar, 2022; Mutanga et al., 2024), which would require a more in-depth integration of microeconomic information on health into the macroeconomic CGE framework.

The REWEFE model, in its current version, proofs as fruitful base for future work; however, as Lemelin and Savard (2022) aptly state: "CGE (and other) models are useful to contribute insights to the policy debate […] while leaving some room for improvement — no model is perfect, no model is complete. It would be fair to say that every model should be considered as a work in progress" (Lemelin and Savard, 2022: 771).

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Appendix

The PEP standard model has been widely applied to different topic, many of them related to single WEFE nexus pillars of W(ater), E(nergy), F(ood) and E(cosystems). In addition to its static formulation also the dynamic version of the standard model, i.e., the PEP-1-t model, has been employed in numerous studies. Table A-1 presents selected studies using the PEP-1-1 or the PEP-1-t model to analyse WEFE nexus related topics, for example, water and climate change (e.g., Vargas et al., 2018), energy and fuel extraction (e.g., Baatarzorig et al., 2018), food and agriculture (e.g., Sawadogo and Maisonnave, 2021, 2024), and emissions (e.g., Chitiga-Mabugu et al., 2022). While the agriculture, food, and energy dimensions of the WEFE nexus are frequently explored in these studies, research explicitly focusing on the water and ecosystem pillars remains less common.

Table A-1: Studies using the PEP-1-1 or PEP-1-t models to address WEFE nexus pillar topics

WEFE Nexus Pillar	Pub. Type	Study
Water/food/agriculture/climate change in Cameroon	WP	Sikube Takamagno et al. (2023)
Water/food/agriculture in Burkina Faso	JA	Koinda et al. (2025)
Climate change/food in Boliva	JA	Escalante and Maisonnave (2023)
Food/agriculture/climate change in Bolivia	JA	Escalante & Maisonnave (2022)
Ecosystem/environment in South Africa	JA	Chitiga-Mabugu et al (2022)
Food/agriculture in South Africa	WP	Mbanda & Ncube (2021)
Food/agriculture in DR of Congo	JA	Joshi et al (2024)
Food in Nigeria	WP	Ikhide et al. (2021)
Ecosystem/climate change/water in Burkina Faso	WP	Sawadogo and Fofana (2021)
Food/agriculture in Burkina Faso	JA	Sawadogo and Maisonnave (2021)
Water/agriculture in Niger	WP	Ide et al. (2019)
Water/food/agriculture/climate change in Guatemala	JA	Vargas et al (2018)
Energy/mining in Mongolia	JA	Baatarzorig et al. (2018)
Energy/mining in Niger	JA	Sangare and Maisonnave (2018)
Energy in South Africa	JA	Henseler and Maisonnave (2018)
Water/food/agriculture in Ethiopia	WP	Beyene and Engida (2013)
Food/agriculture in the Philippines	WP	Corong and Cororaton (2006)

Notes: Pub.Type = Publication Type; WP = Working Paper; JA = Journal Article