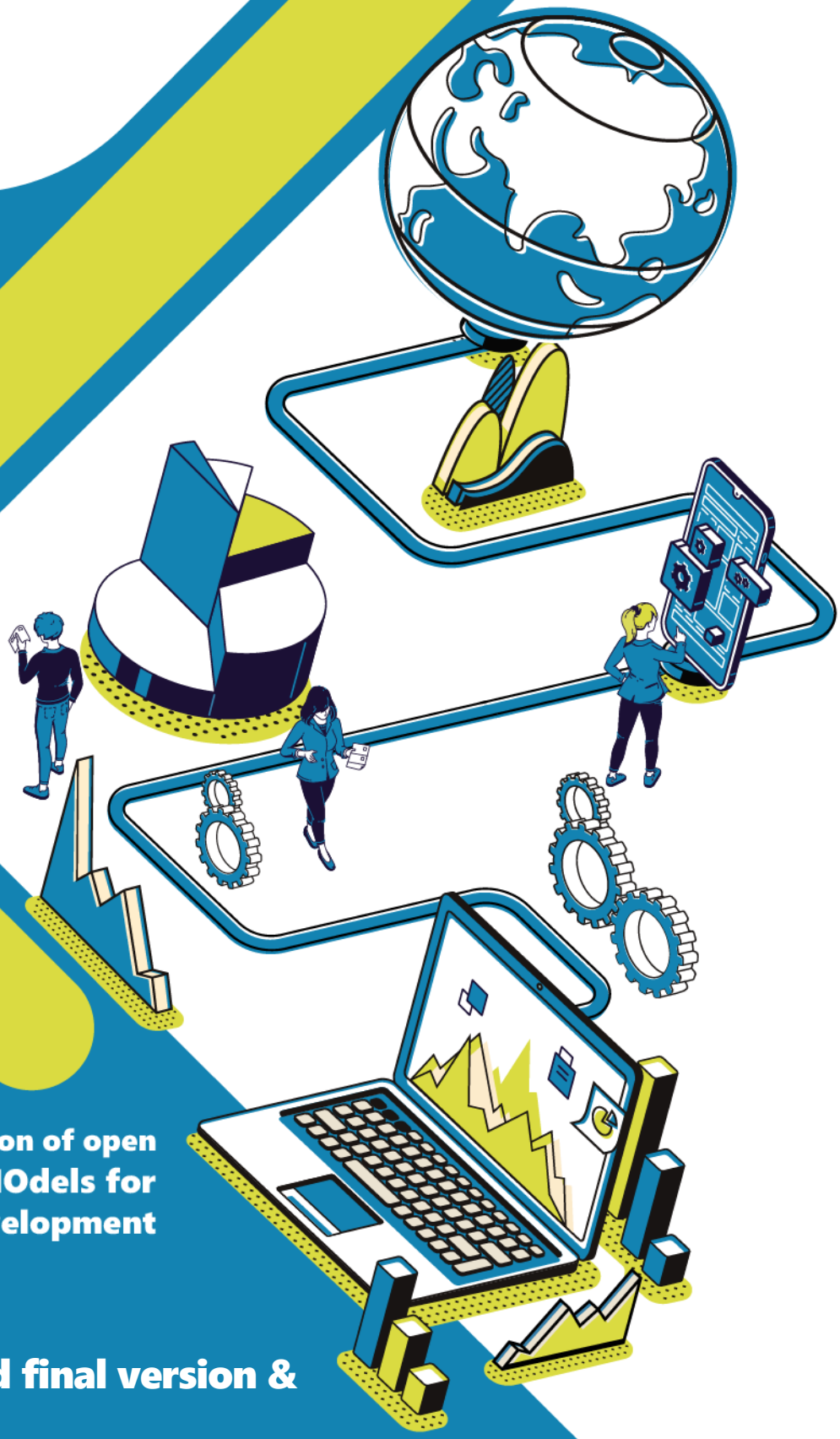
DIAMOND

www.climate-diamond.eu



Delivering the next generation of open Integrated Assessment MOdels for Net-zero, sustainable Development

D3.4 – NEMESIS-World final version & documentation

WP3 – Update & Upgrade

28/11/2025

Funded by the European Union

Disclaimer

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Copyright Message

This report, if not confidential, is licensed under a Creative Commons Attribution 4.0 International License (CC BY 4.0); a copy is available here: https://creativecommons.org/licenses/by/4.0/. You are free to share (copy and redistribute the material in any medium or format) and adapt (remix, transform, and build upon the material for any purpose, even commercially) under the following terms: (i) attribution (you must give appropriate credit, provide a link to the license, and indicate if changes were made; you may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use); (ii) no additional restrictions (you may not apply legal terms or technological measures that legally restrict others from doing anything the license permits).

Grant Agreement Number	101081179		Acronym	DIAMOND
Full Title	Delivering the next generation of open Integrated Assessment MOdels for Net-zero, sustainable Development			
Topic	HORIZON-CL5-2022-D1-02			
Funding scheme	HORIZON EUROPE, RIA – Research and Innovation Action			
Start Date	December 2022	**Duration**	48 Months	
Project URL	http://www.climate-diamond.eu/			
EU Project Advisor	Silvia Vaghi			
Project Coordinator	Institute of Communications and Computer Systems - ICCS			
Deliverable	D3.4 – NEMESIS-World final version & documentation			
Work Package	WP3 – Update & Upgrade			
Date of Delivery	**Contractual**	30/11/2025	**Actual**	28/11/2025
Nature	OTHER	**Dissemination**	Public	
Lead Beneficiary	SEURECO SOCIETE EUROPEENNE D'ECONOMIE SARL (SEURECO)			
Responsible Author	Baptiste Boitier	**Email**	baptiste.boitier@erasme-team.eu	
	SEURECO	**Phone**	-	
Contributors	Hayat Mekki, Pierre Le Mouël, Paul Zagamé, Yossri Dribek (SEURECO)			
Reviewer(s)	Maurizio Gargiulo, Alessia Elia (E4SMA); Marc Vielle (EPFL); Konstantinos Koasidis, Alexandros Nikas (ICCS)			
Keywords	NEMESIS-World; Macroeconomic Model; EXIOBASE; Model Overview; Documentation			

EC Summary Requirements

1. Changes with respect to the DoA

No changes with respect to the work described in the DoA.

2. Dissemination and uptake

The NEMESIS-World model and its accompanying documentation are intended for a wide audience of researchers, policymakers, and analysts working on global economic development, climate mitigation, and long-term structural change. By making all code, data, and technical material openly available, the project supports reproducibility and encourages uptake by academic institutions, international organisations, and policy advisory bodies. The report serves as both a reference for model implementation and a resource for users seeking a transparent, flexible framework for scenario analysis and policy evaluation.

3. Short summary of results (<250 words)

This deliverable presents the final version of the NEMESIS-World model developed under the DIAMOND project. NEMESIS-World is an openly accessible, multi-country, multi-sector macroeconomic modelling framework designed to evaluate the socioeconomic implications of long-term structural policies, including climate transition strategies. Derived from the well-established EU version of the NEMESIS model, it extends the original framework to 22 world regions and offers comprehensive global coverage. Model data and code are publicly available on GitHub accompanied by an online documentation, supporting transparency and reproducibility. The model integrates a system of interconnected regional economies, describing the behaviour of representative firms, households, and governments. Its supply block distinguishes 59 economic activities that combine capital, energy, labour of three skill levels, and intermediate inputs through CES-type production functions. International linkages are captured through bilateral trade flows following an Armington specification, ensuring a realistic differentiation between domestic and imported goods and services. A detailed energy–environment module enhances the model's capacity to assess climate and energy policies by representing energy use in both monetary and physical terms and explicitly modelling electricity generation technologies. This documentation outlines the geographical and sectoral coverage of the model, the global multi-regional input–output datasets underlying its calibration, and the theoretical structure shaping production, consumption, trade, labour markets, and the energy–climate system. It also reports results from a series of internal tests—covering individual model blocks and benchmark carbon price scenarios—and describes the technical requirements and procedures for running the model and constructing baseline scenarios. The finalised NEMESIS-World model serves as a robust platform for global comparative analysis of policy pathways in the DIAMOND project and beyond.

4. Evidence of accomplishment

This report, the GitHub repository of the NEMESIS-World model (https://github.com/Seureco/NEMESIS-World), the model documentation in Read-the-Docs (link), and the relevant model release available through Zenodo (link).

Funded by
the European Union

Preface

DIAMOND will update, upgrade, and fully open six Integrated Assessment Models (IAMs) that are emblematic in scientific and policy processes, improving their sectoral and technological detail, spatiotemporal resolution, and geographic granularity. It will further enhance modelling capacity to assess the feasibility and desirability of Paris-compliant mitigation pathways, their interplay with adaptation, circular economy, and other SDGs, their distributional and equity effects, and their resilience to extremes, as well as robust risk management and investment strategies. This will be done via integration of tools and insights from psychology, finance research, behavioural and labour economics, operational research, and physical science. The project will develop a transdisciplinary scientific approach to legitimise the implementation process and co-create research questions that stretch the frontiers of climate science, as well as establish vibrant communities of practice to transparently open model enhancements and to develop capacities, thereby lowering the entrance barriers to the established IAM community.

ICCS	INSTITUTE OF COMMUNICATIONS AND COMPUTER SYSTEMS	EL
BC3	ASOCIACION BC3 BASQUE CENTRE FOR CLIMATE CHANGE - KLIMA ALDAKETA IKERGAI	ES
CESAR	KRATENA KURT	AT
CICERO	CICERO SENTER FOR KLIMAFORSKNING	NO
CYI	THE CYPRUS INSTITUTE	CY
E4SMA	ENERGY ENGINEERING ECONOMIC ENVIRONMENT SYSTEMS MODELING AND ANALYSIS SRL	IT
HOLISTIC	HOLISTIC IKE	EL
COMILLAS	UNIVERSIDAD PONTIFICIA COMILLAS	ES
ISINNOVA	ISTITUTO DI STUDI PER L'INTEGRAZIONE DEI SISTEMI (I.S.I.S) - SOCIETA'COOPERATIVA	IT
SEURECO	SEURECO SOCIETE EUROPEENNE D'ECONOMIE SARL	FR
UM	UNIVERSITEIT MAASTRICHT	NL
ESMIA	ESMIA CONSULTANTS INC.	CA
USMF	THE UNIVERSITY OF MARYLAND FOUNDATIION INC	US
UMD	UNIVERSITY OF MARYLAND	US
EPFL	ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE	CH
ETH	EIDGENOESSISCHE TECHNISCHE HOCHSCHULE ZUERICH	CH
UNIBAS	UNIVERSITAT BASEL	CH
Imperial	IMPERIAL COLLEGE OF SCIENCE TECHNOLOGY AND MEDICINE	UK
Oxford	THE CHANCELLOR, MASTERS AND SCHOLARS OF THE UNIVERSITY OF OXFORD	UK
UCL	UNIVERSITY COLLEGE LONDON	UK

Executive Summary

This report serves as the technical documentation for the NEMESIS-World model, corresponding to the finalised version released under the DIAMOND project. NEMESIS-World is a multi-country, multi-sector, recursive-dynamic macroeconomic model derived from the existing EU version of the NEMESIS model, first developed and used in the early 2000s. Developed by SEURECO, a French SME, the model's data and code are openly and publicly available on GitHub.

The model integrates a system of interconnected economic models covering 22 world regions. It is designed to analyse challenges related to economic development, competitiveness, employment, and long-term structural policies such as climate transition strategies. Its primary objective is to evaluate the socioeconomic effects of various policies through comparative analyses based on scenario simulations.

At its core, the model describes the behaviour of representative agents—firms, households, and governments. On the supply side, it distinguishes 59 economic activities producing goods and services through CES-type production functions that combine multiple inputs: capital, energy, low-, medium-, and high-skilled labour, and intermediate goods. These sectors are linked through inter-industry exchange matrices and international trade. Trade flows are modelled bilaterally under an Armington specification, distinguishing between imported and domestically produced goods and services. NEMESIS-World also includes a detailed energy–environment module, which enhances its capacity to evaluate climate mitigation policies. This module refines the representation of each region's energy system by specifying energy use across sectors and households in monetary, as well as physical, units. It also allows for the explicit modelling of the power generation sector, allocating electricity production among different technologies.

Section 1 introduces core aspects of the model, including geographical and sectoral coverage, while Section 2 reviews the global multi-regional input-output databases used as data sources. Section 3 provides details on the structure of the model, elaborating on the theoretical underpinning of the supply block, household consumption and its allocation, international trade, labour market, and the energy–climate module. Section 4 provides the outcomes of two test series conducted with NEMESIS-World: the first focusing on individual model blocks (supply, households, trade, and power generation), and the second on benchmark simulations of carbon price scenarios. Finally, Section 5 outlines the technical requirements to generate and run the model, as well as the procedures for creating baseline scenarios.

Funded by
the European Union

Contents

1 NEMESIS-World model overview 1
1.1 Overview of core features 1
1.2 Note of version 2
1.3 Geographical coverage 2
1.4 Sectoral coverage 5
1.5 Other core dimensions 7
1.5.1 Labour demand 7
1.5.2 Energy products 7
1.5.3 Power technologies 8
1.5.4 GHG emissions 8
2 Data and data processing 9
2.1 GMRIO review 9
2.2 Main economic variables 11
2.2.1 Variables retrieved from EXIOBASE 11
2.2.2 Gross fixed capital formation 12
2.2.3 Agents' accounts: households and governments 13
2.3 Energy data 14
2.4 GHG emissions data 14
2.5 Other data 14
3 Theoretical aspects and detailed modelling features 15
3.1 General structure 15
3.2 Supply side 17
3.3 Households' consumption 19
3.4 International Trade 22
3.5 Labour market 22
3.6 Energy and climate module 23
4 Evaluating the model's response to shocks 25
4.1 Testing the model block by block 25
4.1.1 Supply block 25
4.1.2 Households' aggregated consumption 29
4.1.3 Households' consumption allocation 29
4.1.4 Trade block 31
4.1.5 Power generation 33
4.2 Test the model as a whole 34
5 Model Manual 40
5.1 Software 40

5.2 Model and baseline generation 40
References 42
Appendix 44

Table of Figures

Figure 1. Map of NEMESIS World geographical coverage 3
Figure 2. General structure of MRIO databases 9
Figure 3. Illustrative figure of inter-region and inter-industry exchanges in the aggregated version of EXIOBASE used in NEMESIS World, for the year 2019 12
Figure 4. Illustrative figure of inter-region and inter-industry capital flows in NEMESIS World, for year 2019 13
Figure 5. NEMESIS-World general scheme 16
Figure 6. Production function nested structure 17
Figure 7. Literature review summary results for CES substitution elasticity by industry and bundle 18
Figure 8. Households' consumption nested structure 21
Figure 9. Sector production factors deviation after an increase of 20% of low-qualified workers in Mexico in 2030 26
Figure 10. Sector production factors deviation after an increase of 1 ppt of real interest rate in Italy in 2030 27
Figure 11. Sector production factors deviation after an increase of 100% of energy price in Japan in 2030 28
Figure 12. US households' consumption variations after a shock of 10% of real income 29
Figure 13. Variations of households' consumption by purpose after an increase of 50% of refined oil prices in USA in 2030 30
Figure 14. Variations of households' consumption by purpose after an increase of 20% of food industry prices in USA in 2030 31
Figure 15. Deviation by sector of domestic demand, imports and exports after an increase of 10% of production price in China in 2030 32
Figure 16. Deviation of CO_2 emissions in power generation after the implementation of a carbon tax of 100€/tCO_2 in 2030 in all countries 33
Figure 17. Power generation changes without and with a carbon tax of 100€/tCO_2 in 2030 in all countries 34
Figure 18. CO_2 emissions from fossil fuels combustion in the benchmark scenarios 35
Figure 19. Power generation mix in the benchmark scenarios in all countries 36
Figure 20. Final energy consumption by sector in the benchmark scenarios in all countries 37
Figure 21. Final energy consumption by fuel in the benchmark scenarios in all countries 38
Figure 22. Scheme of the model and baseline generation 41

Table of Tables

Table 1. NEMESIS World geographical coverage mapping 4
Table 2. NEMESIS World sectoral coverage 6
Table 3. NEMESIS World - Levels of qualification of employment 7
Table 4. NEMESIS World – Energy products 7
Table 5. NEMESIS World – Power generation technologies 8
Table 6. NEMESIS World – Greenhouse gases 8
Table 7. Synthesis of the main features of GMRIO databases 10

Funded by the European Union

Table 8. List of variables directly retrieved from EXIOBASE 11
Table 9. *Power generation parameters (illustrative case of 2030 for "Rest of EU" region)* 23
Table 10. List of shocks introduced in the model block by block 25
Table 11. Illustrative diagnostic scenario adapted from Kriegler et al. (2015) 34
Table 12. Software requirements 40
Table 13. NEMESIS World regions' mapping with EXIOBASE 44
Table 14. NEMESIS World sectors' mapping with EXIOBASE 45
Table 15. Mapping of Households' consumption categories with economic activities 50

Funded by
the European Union

1 NEMESIS-World model overview

1.1 Overview of core features

NEMESIS-World is a multi-country, multi-sector, recursive dynamic macroeconomic model derived from the EU NEMESIS model[1], first developed and used in the early 2000s (Brécard et al. 2006; Boitier et al. 2022). It is designed to assess the socioeconomic impacts of structural and climate-related policies through scenario-based comparative analyses. The model distinguishes 59 production activities using CES-type technologies that combine capital, energy, differentiated labour inputs, and intermediate goods. These activities are connected via inter-industry linkages and bilateral trade flows following an Armington specification. A dedicated energy–environment module provides a detailed representation of regional energy systems, including sectoral and household energy use, and an explicit modelling of electricity generation technologies. Developed by SEURECO, the model's full data and codebase are openly accessible on GitHub[2].

The model offers a global coverage, distinguishing 22 different regions: sixteen individual countries—representing the world's largest economies—and six aggregated regions, one of which represents the non-disaggregated EU countries. The other aggregated regions cover four different geographical areas, allowing the model to align with the standardised regional classifications used in IPCC reporting. This level of regional detail is crucial for analysing decarbonisation policies, at the level of individual countries or regions. In terms of sectoral coverage, the model includes more than fifty distinct economic activities. This high level of sectoral disaggregation enables detailed assessments of the economic impacts of various structural policies, particularly those targeting specific sectors. The sectors have been selected based on their relevance to greenhouse gas (GHG) mitigation technologies. Accordingly, key industrial sectors such as glass, cement and lime, iron and steel, and aluminium manufacturing are explicitly represented. Similarly, the transport sector is disaggregated into sea and coastal shipping, inland waterways, air transport, railways, and other land transport. Beyond technological aspects, the energy supply sector is also comprehensively represented, including sectors such as coal mining, oil and natural gas extraction, and the production of coke, petroleum and nuclear products, gas, and electricity.

The model is well-suited for assessing employment impacts of structural changes, due to the detailed representation of economic activities and the disaggregation of workers into three qualification levels: low-, medium-, and high-skilled. This distinction significantly improves the accuracy and policy relevance of the model's quantitative employment impact assessments, as employment effects are often a central concern for policymakers. Another key feature of the model is its macro-econometric foundation, which distinguishes it from other typical general equilibrium models (Nikas et al. 2019). Specifically, it can be classified as a neo-Keynesian model, allowing for short-term market disequilibria. In particular, the model accounts for non-structural unemployment in the short-run and incorporates behavioural adjustments that gradually converge towards medium- and long-term optimal behaviours. This approach enables the model to capture short-term rigidities while maintaining long-term structural equilibrium. Finally, the model also captures income flows for households and governments, enabling the assessment of the income effects of structural policies.

[1] Full documentation available here: https://www.erasme-team.eu/en/the-nemesis-model/ & Synthetic documentation (including EU version) here: https://iamparis.eu/detailed_model_doc/47

[2] https://github.com/Seureco/NEMESIS-World

1.2 Note of version

The version presented here corresponds to the final version (v1.00) of the model developed within DIAMOND including both the economic core and the energy module. A permanent link to this version can be found in Zenodo: https://zenodo.org/records/17753365. The data for this final version have been released on GitHub and are accessible online: https://github.com/Seureco/NEMESIS-World under a "*Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License*" (http://creativecommons.org/licenses/by-nc-sa/4.0/). The coding of the model is also available online, on the same repository under an Apache 2.0 license with the addition of the "Commons Clause" restrictions[3], and it allows the generation of a "flat" reference scenario, used herewith to test the model's properties. The documentation of the model is available on documentation hosting platform Read the Docs (https://nemesis-world.readthedocs.io).

1.3 Geographical coverage

The geographical coverage of the NEMESIS-World model includes 22 different regions, 16 of which represent the largest economies of the World. In 2022, those 16 countries represented 75% of the global GDP, 55% of the population (International Monetary Fund 2025) and 70% of global GHG emissions (Crippa, M. et al. 2024). The remaining regions are grouped in 6 different geographical zones. Such regional detail, covering major economies, is important when assessing decarbonisation policies that are mostly country or region-specific whereas, six different geographical areas for the non-disaggregated countries allows the model to be able to map with general IPCC standardised reporting regions. The 22 regions covered are:

- Africa: all African countries (named RoW Africa, WF)
- America: Canada (CA), Brazil (BR), Mexico (MX), United States of America (US) and the rest of American countries (RoW America, WL)
- Asia and Pacific: Australia (AU), China (CN), South Korea (KR), India (IN), Indonesia (ID), Japan (JP), Russia (RU), the rest of Asian and Pacific countries (RoW Asia & Pacific, WA) and the Middle East countries (RoW Middle East, WM)
- Europe: France (FR), Germany (DE), Italy (IT), Spain (ES), the United Kingdom (UK), the Rest of European Union Member States (Rest of EU, OE) and the rest of European Countries (RoW Europe, WE)

The detailed geographical coverage is presented in Table 1 and illustrated in Figure 1.

[3] See details on the GitHub repository: https://github.com/Seureco/NEMESIS-World/blob/main/LICENSE

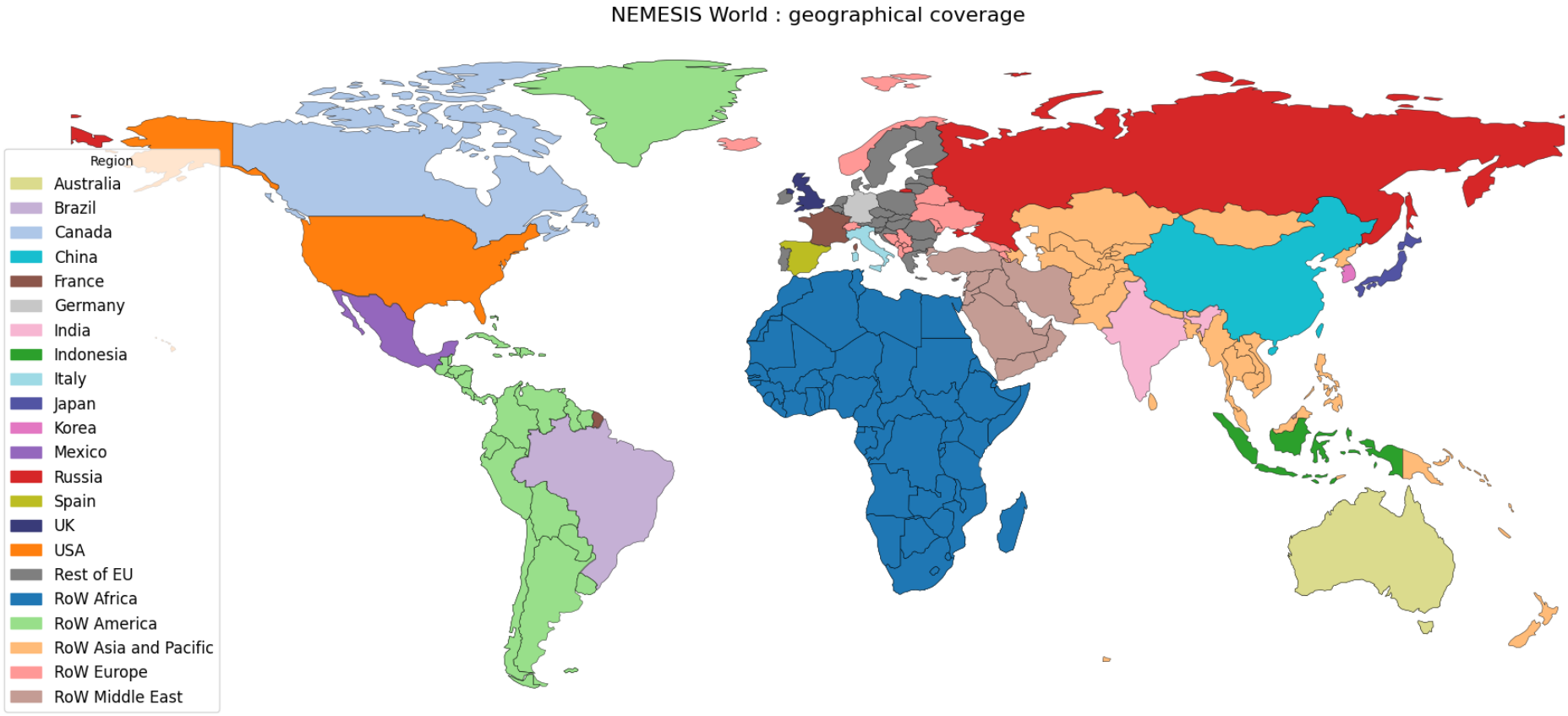


Figure 1. Map of NEMESIS World geographical coverage

Funded by
the European Union

Table 1. NEMESIS World geographical coverage mapping

Africa	**RoW Africa (WF)**	Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe, Western Sahara
America	**Canada (CA)**	Canada
	Brazil (BR)	Brazil
	Mexico (MX)	Mexico
	USA (US)	United States of America
	RoW America (WL)	Argentina, Chile, Haiti, Dominican Rep., Bahamas, Falkland Is., Greenland, Uruguay, Bolivia, Peru, Colombia, Panama, Costa Rica, Nicaragua, Honduras, El Salvador, Guatemala, Belize, Venezuela, Guyana, Suriname, Ecuador, Puerto Rico, Jamaica, Cuba, Paraguay, Trinidad and Tobago, Antigua and Barbuda, Barbados, Dominica, Grenada, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines
Asia & Pacific	**Australia (AU)**	Australia
	China (CN)	China
	India (IN)	India
	Indonesia (ID)	Indonesia
	Japan (JP)	Japan
	South Korea (KR)	South Korea
	Russia (RU)	Russia
	RoW Asia & Pacific (WA)	Kazakhstan, Uzbekistan, Turkmenistan, Kyrgyzstan, Tajikistan, Afghanistan, Bangladesh, Bhutan, Nepal, Pakistan, Sri Lanka, Maldives, Timor-Leste, Brunei, Cambodia, Thailand, Laos, Myanmar, Vietnam, Philippines, Malaysia, North Korea, Mongolia, Azerbaijan, Papua New Guinea, Vanuatu, Solomon Is., New Caledonia, New Zealand, Fr. S. Antarctic Lands, Fiji, Tonga, Samoa, Micronesia, Palau, Tuvalu, Kiribati, Nauru, Singapore
	RoW Middle East (WM)	Lebanon, Palestine, Jordan, United Arab Emirates, Qatar, Kuwait, Iraq, Oman, Iran, Israel, Syria, Turkey, Yemen, Saudi Arabia, N. Cyprus, Bahrain
Europe	**France (FR)**	France
	Germany (DE)	Germany
	Italy (IT)	Italy
	Spain (ES)	Spain
	The United-Kingdom (UK)	United-Kingdom
	Rest of EU (OE)	Sweden, Poland, Austria, Hungary, Romania, Lithuania, Latvia, Estonia, Bulgaria, Greece, Croatia, Luxembourg, Belgium, Netherlands, Portugal, Ireland, Denmark, Slovenia, Finland, Slovakia, Czechia, Cyprus, Malta
	RoW Europe (WE)	Norway, Armenia, Belarus, Ukraine, Moldova, Albania, Switzerland, Iceland, Georgia, Bosnia and Herzegovina, North Macedonia, Serbia, Montenegro, Kosovo, Andorra, Azerbaijan, Liechtenstein, Monaco, San Marino

Funded by the European Union

1.4 Sectoral coverage

The model represents 59 different economic activities for each region modelled. This high level of sectoral detail allows the model to provide detailed economic impact assessments. Particular emphasis has been placed on disaggregating sectors impacting or be impacted by climate change mitigation options.

The economic activities include the following disaggregated sectors:

- Four agricultural sectors: Agriculture – vegetable; Agriculture – animals; Forestry; and Fishery.
- Four mining and quarrying sectors: Mining of coal; Extraction of oil; Extraction of natural gas; and Other mining.
- Thirteen energy intensive industries: Manufacture of pulp, paper and printing products; Manufacture of coke; Manufacture of petroleum and nuclear products; Chemicals – plastics; Chemicals – fertilisers; Chemicals – others; Manufacture of rubber and plastic products; Manufacture of glass; Manufacture of cement and lime; Manufacture of other non-metallic mineral products; Manufacture of iron and steel; Manufacture of other basic metals and Aluminium production.
- Eleven other manufacturing industries: Manufacture of food, beverage and tobacco; Manufacture of textiles, wearing apparel and leather products; Manufacture of wood and wood products; Manufacture of fabricated metal products; Manufacture of machinery and equipment; Manufacture of office machinery and computers; Manufacture of electrical machinery and apparatus; Manufacture of radio, television and communication equipment and apparatus; Manufacture of medical, precision and optical instruments, watches and clocks; Manufacture of motor vehicles, trailers and semi-trailers; Manufacture of other transport equipment and Other manufacturing.
- Eight utilities: Wastes treatment and recycling; Production of electricity; Transmission of electricity; Distribution and trade of electricity; Manufacture of gas; distribution of gaseous fuels through mains; Steam and hot water supply and Water distribution.
- One construction sector: Construction.
- Six transportation related sectors: Transport via railways; Other land transport; Sea and coastal water transport; Inland water transport; Air transport and Other transport.
- Eight market services: Trade; Hotels and restaurants; Finance; Insurance; Real estate activities; Information and communication; Research and development; Other business activities.
- Four non-market services: Public administration and defence; compulsory social security; Education; Health and social work and Other services activities.

Table 2. NEMESIS World sectoral coverage

01	Agriculture - vegetable	31	Manufacture of motor vehicles, trailers and semi-trailers
02	Agriculture - animals	32	Manufacture of other transport equipment
03	Forestry	33	Other manufacturing
04	Fishery	34	Wastes treatment and recycling
05	Mining of coal	35	Production of electricity
06	Extraction of oil	36	Transmission of electricity
07	Extraction of natural gas	37	Distribution and trade of electricity
08	Other mining	38	Manufacture of gas; distribution of gaseous fuels through mains
09	Manufacture of food, beverage and tobacco	39	Steam and hot water supply
10	Manufacture of textiles, wearing apparel and leather products	40	Water distribution
11	Manufacture of wood and wood products	41	Construction
12	Manufacture of pulp, paper and printing products	42	Trade
13	Manufacture of coke	43	Hotels and restaurants
14	Manufacture of petroleum and nuclear products	44	Transport via railways
15	Chemicals - plastics	45	Other land transport
16	Chemicals - fertilisers	46	Sea and coastal water transport
17	Chemicals - others	47	Inland water transport
18	Manufacture of rubber and plastic products	48	Air transport
19	Manufacture of glass	49	Other transport
20	Manufacture of cement and lime	50	Finance
21	Manufacture of other non-metallic mineral products	51	Insurance
22	Manufacture of iron and steel	52	Real estate activities
23	Manufacture of other basic metals	53	Information and communication
24	Aluminium production	54	Research and development
25	Manufacture of fabricated metal products	55	Other business activities
26	Manufacture of machinery and equipment	56	Public administration and defence; compulsory social security
27	Manufacture of office machinery and computers	57	Education
28	Manufacture of electrical machinery and apparatus	58	Health and social work
29	Manufacture of radio, television and communication equipment and apparatus	59	Other services activities
30	Manufacture of medical, precision and optical instruments, watches and clocks		

Energy Intensive Industries

1.5 Other core dimensions

1.5.1 Labour demand

The model distinguishes three different levels of qualification of the workforce for each economic activity in each region, based on the standardisation of the International Standard Classification of Education (ISCED) presented in Table 3.

Table 3. NEMESIS World - Levels of qualification of employment

Level of qualification	International Standard Classification of Education (ISCED)
Low-qualified	0 Less than primary education 1 Primary education 2 Lower secondary education
Medium-qualified	3 Upper secondary education 4 Post-secondary non-tertiary education
High-qualified	5 Short-cycle tertiary education 6 Bachelor's or equivalent level 7 Master's or equivalent level 8 Doctoral or equivalent level

1.5.2 Energy products

Beyond the aggregated demand reflected in monetary units, the model also quantifies the demand for twelve different energy commodities, presented in Table 4.

Table 4. NEMESIS World – Energy products

Primary energy		Secondary energy	
Fossil fuels	Oil Natural gas Coal	Electricity	Oil Natural gas Coal Solid biomass Biogas Liquid biofuel Wastes Nuclear Geothermal Wind Solar Hydro Tidal
Renewable energy sources	Solid biomass Biogas Liquid biofuel Wastes (50%)*	Heat	Oil Natural gas Coal Solid biomass Biogas Liquid biofuel Industrial and municipal wastes Nuclear Geothermal
Other energy commodities	Geothermal Solar thermal Wastes (50%)*		

**: by definition 50% of wastes are assumed as renewable and 50% non-renewable*

1.5.3 Power technologies

The sector "*Production of electricity*" is detailed to cover numerous power technologies presented in Table 5.

Table 5. NEMESIS World – Power generation technologies

Fossils	Coal without CCS
	Coal with CCS
	Natural gas without CCS
	Natural gas with CCS
	Oil
Renewable sources	Hydro
	Wind onshore
	Wind offshore
	PV
	CSP
	Solid biomass without CCS
	Solid biomass with CCS
	Liquid biofuel
	Biogas
	Tidal
	Geothermal
	Renewable wastes
Other	Nuclear
	Non-renewable wastes

NB: CCS: carbon capture and storage; PV: photovoltaic; CSP: concentrated solar power

1.5.4 GHG emissions

The model also calculates the following GHG emissions: CO_2, N_2O, CH_4, F-gases (Table 6).

Table 6. NEMESIS World – Greenhouse gases

CO_2	Carbon dioxide
N_2O	Nitrous oxides
CH_4	Methane
F-gases	Fluorinated gases including: • Hydrofluorocarbon (HFCs) • Fluorocarbon (PFCs) • Sulphur hexafluoride (SF_6) • Nitrogen trifluoride (NF_3)

2 Data and data processing

The NEMESIS-World model uses different databases, with the main source for the economic data being the EXIOBASE v3.8.2 (Stadler et al. 2021)[4].

2.1 GMRIO review

Global Multi Regional Input-Output (MRIO) tables typically offer key data for large-scale macroeconomic models. These databases have a worldwide coverage and describe the economic exchanges between economic activities and regions (inter-industry exchanges), the final demand by region, the value added and production and, in some cases, satellite accounts on economic inputs or environment (see general structure of MRIO database in Figure 2).

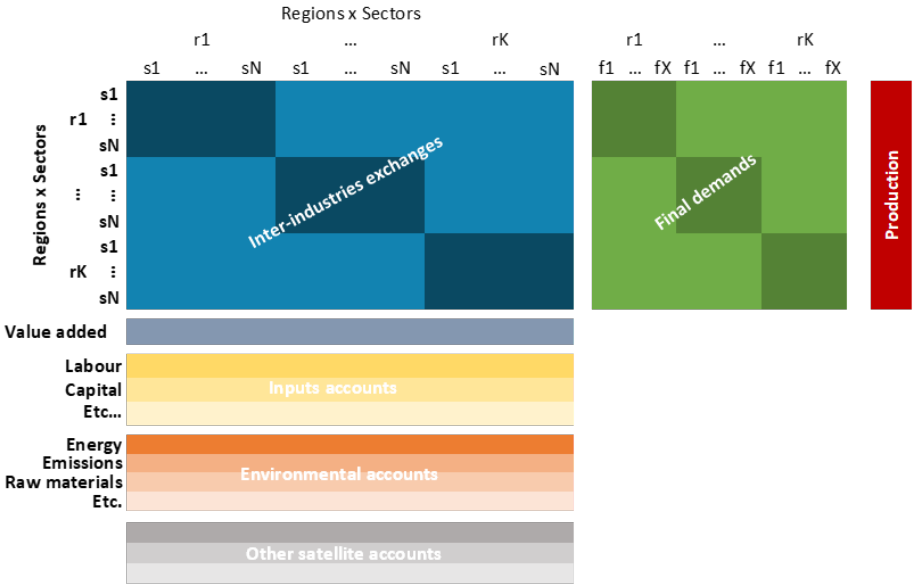


Figure 2. General structure of MRIO databases

Prior to the data processing work required for the NEMESIS-World model, we performed a review of existing MRIO databases and tried to appraise the relevance of each dataset for the NEMESIS-World model. Table 7 summarises some key characteristics of the reviewed MRIO database[5]. We focused on fully or partially open GMRIO, excluding non-free databases, such as GTAP[6]. We added in brackets a score (+): moderate, (++): good or (+++): very good, reflecting the level of granularity for the geographical, or sectoral coverage, the availability of additional variables in the satellite accounts, and an appraisal of data accuracy. Based on this review, we chose to rely on EXIOBASE due to the: (i) extensive geographical coverage, including multiple "Rest of the World" regions, which is valuable for climate mitigation policy assessments and IPCC reporting; (ii) highly detailed sector disaggregation, enabling modelling key industrial and transport sectors in mitigation analyses; and (iii) legitimacy within the scientific community, which provides confidence in the reliability of the underlying data.

[4] https://zenodo.org/records/5589597. The database is provided free of charge to users under a CC-BY-SA license.
[5] This review has been performed on Summer 2024. Since thennew versions have been published, e.g. EXIOBASE v3.9.x from January 2025.
[6] https://www.gtap.agecon.purdue.edu/databases/default.asp

Table 7. Synthesis of the main features of GMRIO databases

Name	Version	Coverage			Satellite accounts		Reference	Link	Note	Own appraisal on data accuracy
		Regions	Sector	Year	Economic inputs	Environment				
ADB	August 23	62 to 71 *(++)*	35 *(+)*	2000-2022 *(+++)*				link		*(+++)*
EMERGING	v2	245 *(+++)*	135 *(+++)*	2015-2019 *(++)*			Huo et al. (2022)	link	Relatively new dataset: not yet popular	*(+)*
EORA	full	190 *(+++)*	Differ according to regions: 15990 in total, 80 per region on average *(+++)*	1990-2022 *(+++)*	Employment (by sector, by gender) *(++)*	GHG emissions; Material usage; N and P emissions; Crop and Pasture Area; Crop Area, Production, and Average Yield; Water Use ;Nitrogen; Energy (no more updated) *(+++)*	Lenzen et al. (2013)	link	Not open access (fee for business and free for academia)	*(+)*
	eora26	190 *(+++)*	26 *(+)*	1990-2022 *(+++)*	*Idem*	*Idem*	*Idem*	*Idem*		*(+)*
EXIOBASE	v3.8.2	49 *(++)*	163 *(+++)*	1995-2022 *(+++)*	Employment (by sector, skill and gender and in persons and hours) *(+++)*	Energy (up to 2015); GHG emissions (up to 2019); Air pollutants (up to 2011); Land use (2011); Materials (2013); Water use (2011) *(+++)*	Stadler et al. (2021)	link	Cover Rest of the World in 5 regions All EU Member States 17 non-EU individualised country	*(++)*
	v3rx	206 *(+++)*	163 *(+++)*	1995-2015 *(+)*	Employment (by sector, skill and gender and in persons and hours) *(+++)*	Land use (2015) *(+)*	Bjelle et al. (2020)	link		*(+)*
FIGARO	Edition 2022	46 *(++)*	64 *(++)*	2010-2020 *(++)*			Eurostat (2021)	link		*(+++)*
GLORIA	Release 057	164 *(+++)*	120 *(+++)*	1990-2027 *(+++)*	Employment, skill *(++)*	Material; Energy; Biodiversity; Water use; GHG emissions; Air pollutants *(+++)*	Lenzen et al. (2021)	link		*(+)*
OECD-ICIO	Nov. 2021	71 *(++)*	45 *(++)*	1995-2018 *(+++)*			OECD (2024c)	link		*(+++)*

2.2 Main economic variables

2.2.1 Variables retrieved from EXIOBASE

EXIOBASE is a Global Multi-Regional Input-Output (GMRIO) dataset that includes a set of satellite accounts. Data are available from 1995 to 2022, with the last two years (2021 and 2022) being based on top-down projections. All values are expressed in monetary units (current million euros). The reference year used for the model is 2019, avoiding 2020 because of COVID-19, while the projected years are set for 2021 and 2022. The model directly uses the data presented in Table 8 from the database by region and by country (see Table 13 and Table 14 in Appendix for the mapping between EXIOBASE and NEMESIS-World regions and sectors).

Table 8. List of variables directly retrieved from EXIOBASE

Variables	Region	Sector/product	Agents/Final Uses
Production	x	x	
Intermediate consumption (excluding energy)	x	x	
Energy consumption	x	x	
Gross fixed capital formation	x		
Employment by level of qualification	x	x	
Value added	x	x	
Imports by origin	x	x	x
Exports by origin	x	x	x
Demands addressed (intermediate consumption, gross fixed capital formation, final consumptions)	x	x	x
Households' final consumption	x	x	x
NPISH final consumption	x	x	x
Government final demand	x	x	x
Change in inventories	x	x	
Compensation of employees	x	x	
Gross operating surplus	x	x	
Taxes less subsidies on products purchased	x	x	
Other net taxes on production	x	x	

Note: All retrieved variables are in current million euros.

Figure 3 illustrates the data showing intermediate consumption demand (x-axis) and supply (y-axis) across 59 economic activities and 22 regions. The diagonal of the figure appears darker, indicating that domestic exchanges of intermediate consumption dominate. However, other exchange patterns are also visible, such as the demand from the Rest of Asia and Pacific (WA) to China (CN) — corresponding to x-axis: CN and y-axis: WA.

Despite the availability of information in EXIOBASE, some variables needed in the NEMESIS-World were not available in the database, such as the gross fixed capital formation (only available at the regional level, see Table 8) and the income accounts for households and governments. In the next sub-sections, we discuss the strategy to address these gaps.

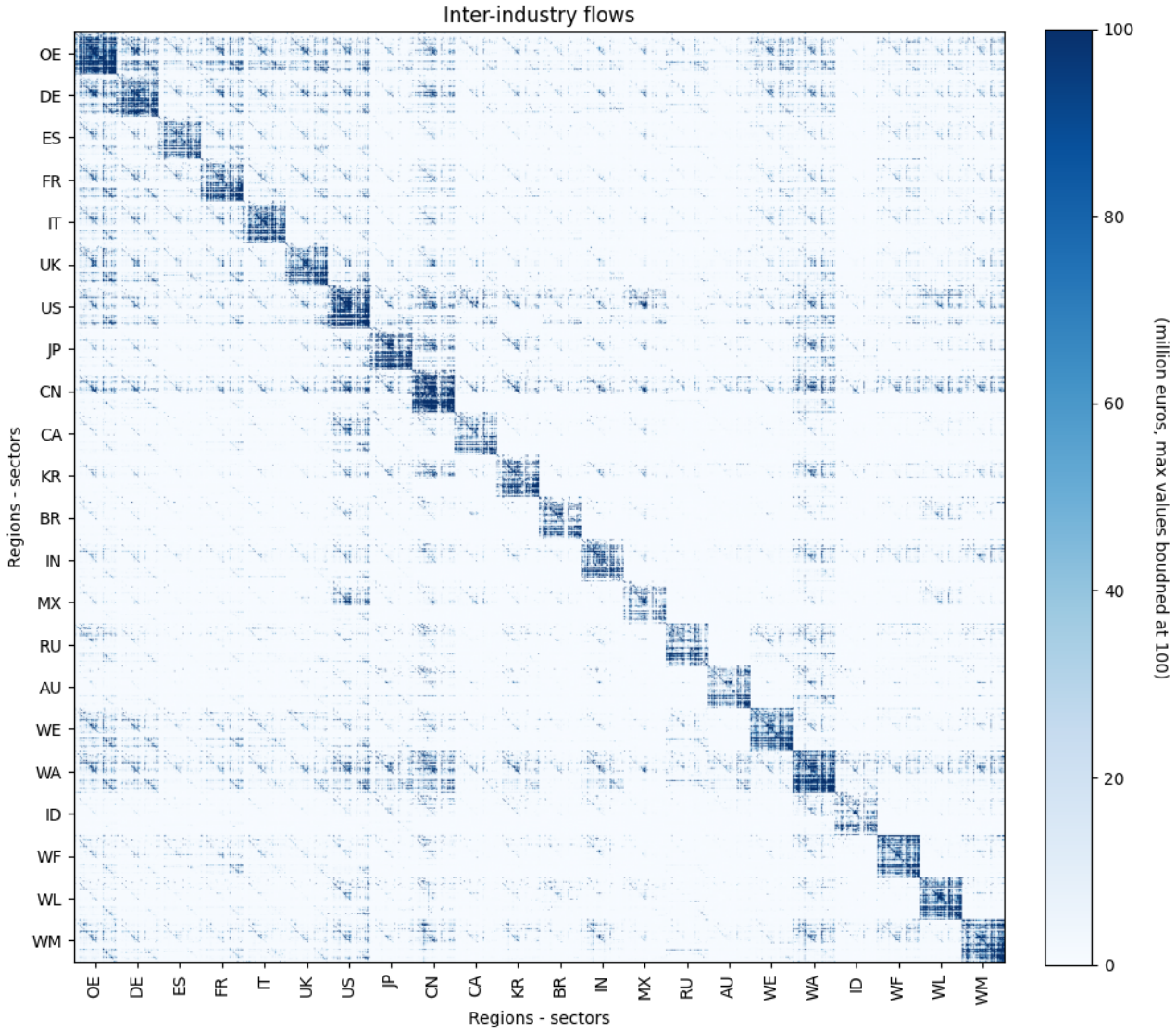


Figure 3. Illustrative figure of inter-region and inter-industry exchanges in the aggregated version of EXIOBASE used in NEMESIS World, for the year 2019

Source: Authors' calculation based on EXIOBASE v3.8.2 (Stadler et al., 2021)

2.2.2 Gross fixed capital formation

EXIOBASE provides information on total gross fixed capital formation (GFCF) for each region, and on the sector and region that produce these capital goods (supplying region and sector). Thus, the region and sector supplying the capital goods and the region demanding them are available in EXIOBASE, but not the demanding sector.

To calculate the GFCF by demanding region and sector, we calculate the GFCF intensity for each sector, i.e., GFCF divided by the level of production (or value added in some case) using different data sources. The main source (OECD 2024a) allows the calculation of these intensities for ten regions: Canada, Germany, Spain, France, United-Kingdom, Italy, Japan, Mexico, other EU countries and USA. For the remaining countries (Australia, China, India, South Korea, Russia and Saudi Arabia as a proxy of the region 'RoW: Middle-East'), we used other sources, mainly based on the national statistical offices. Finally for the regions without statistical information (Brazil, RoW Asia & Pacific, RoW Europe, RoW Africa and RoW America) we proxied the GFCF intensity with the intensity of the geographically closest region(s) with available data. Once all GFCF intensities are calculated, we calculated their 5

years average value, 2015-2019 (when feasible). Thereafter, we multiplied this mean intensity by region and sector by the EXIOBASE production level to calculate first estimates of GFCF by region and sector. We rescaled these values to ensure the sum for each region equals the total value of GFCF by region in EXIOBASE, leading to the final value of GFCF by region and sector used in the model.

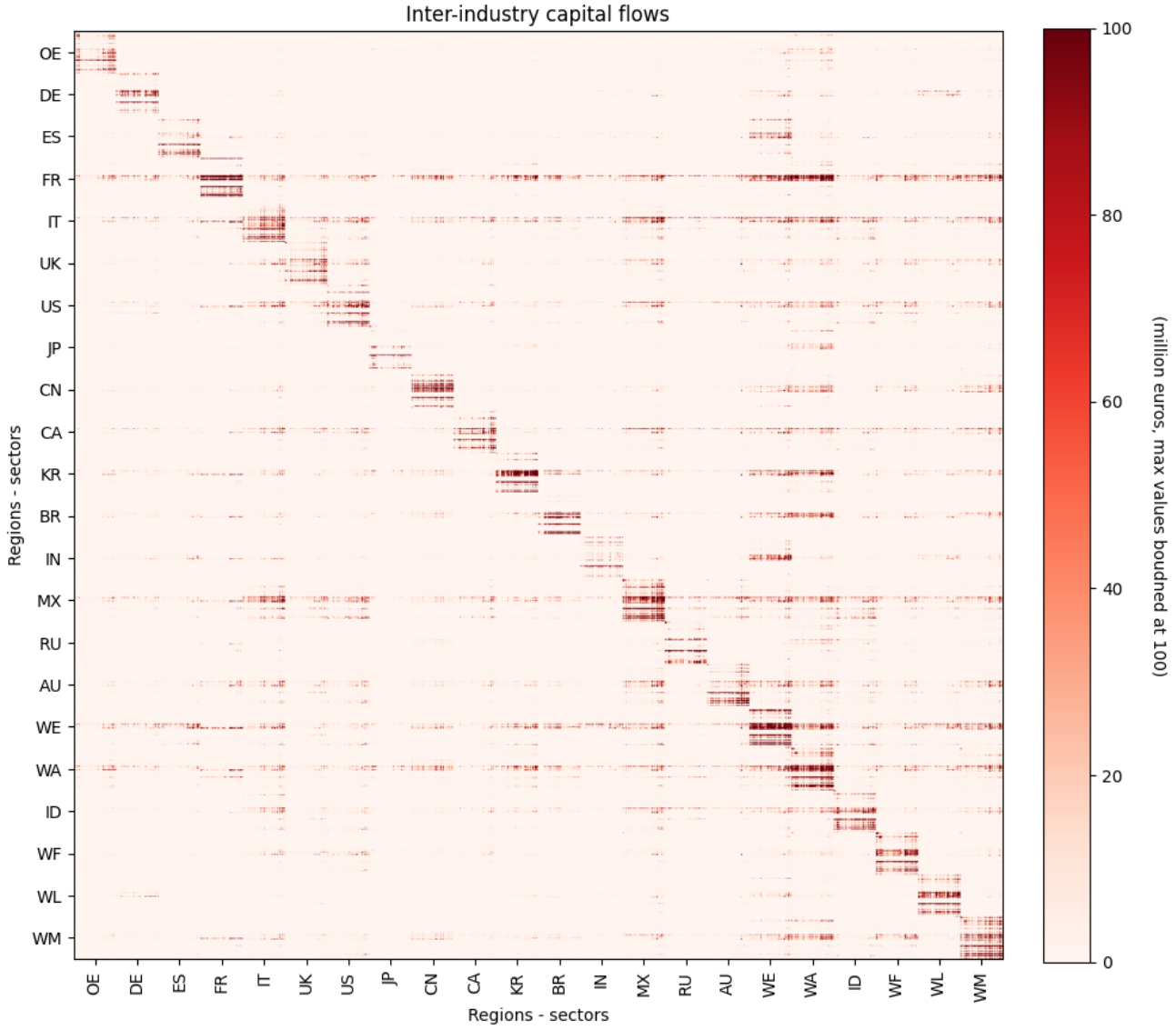


Figure 4. Illustrative figure of inter-region and inter-industry capital flows in NEMESIS World, for year 2019

Source: Authors calculation based on several raw sources (see explanations in section 3.2.2)

As with the Figure 3 for intermediate consumption, Figure 4 illustrates cross-sector and cross-region exchanges of GFCF in 2019, with demand on the x-axis and supply on the y-axis. Once again, the diagonal appears darker, confirming that, despite international exchanges of investment goods, domestic exchanges dominate.

2.2.3 Agents' accounts: households and governments

EXIOBASE delivers information on households' income, limited to the compensation of employees. Although this represents a large share of a household's income, it does not represent all potential sources. To complete these data, we used sector national accounts from OECD (2024b) that deliver statistical information for 45 countries. First, we calculate the gross balance of primary income using EXIOBASE information on compensation of employees (assuming that all are received by households) and gross operating surplus (only at the regional level—

the share allocated to households is calculated based on OECD data). All other components of the gross balance of primary income (property incomes received and paid) are calculated from OECD data but are scaled on EXIOBASE based on the compensation of employees. A similar methodology is used for the calculation of the households' gross disposable income (composed of global primary income, direct tax paid, social contribution received and paid, social benefits received and paid and current transfers received and paid), gross saving (calculated as the gross disposable income minus the households' consumption expenditures and adjusted for the change in pension entitlements) and net lending and borrowing (the gross savings plus net capital transfers and minus households' gross capital formation and acquisitions less disposals of non-financial non-produced assets).

We also do similar calculations for the government income using final consumption as a benchmark, instead of compensation of employees used for households.

2.3 Energy data

To ensure harmonisation across DIAMOND models, NEMESIS-World uses energy balances from the OMNIA model, which are based on processed and corrected data from UN Energy Statistics (UNData 2025b) and the UN Energy Balance (UNData 2025a). However, due to differences in geographical coverage between the two models, some OMNIA regions (i.e., Australia, Indonesia, Germany, France, Italy, and Spain) need to be split from their respective OMNIA aggregates to match the NEMESIS-World regional disaggregation. To do this, we used the raw UN Energy Balance data to calculate the share of each of these countries within their aggregated OMNIA region. These shares are then applied to the OMNIA dataset, allowing us to disaggregate these countries while maintaining overall consistency and preserving the data processing performed for the OMNIA model.

On top of energy quantities, the model requires energy prices to link physical units with monetary units. For the reference year, we used the IEA Energy Prices datasets (IEA 2025, namely the "*Energy Prices and Taxes*" and "*Energy Prices Taxation Information*"). These datasets offer partial information on wholesale and industrial energy prices, both with and without taxes, for oil, natural gas, solid fuels, and electricity and for numerous countries, beyond OECD countries. Since the data are incomplete, we supplemented them with taxation information from OECD (2019), covering excise duties and carbon taxes. We then processed these data to derive consistent energy prices—with and without taxes—for industries, power generation, households, and services.

2.4 GHG emissions data

GHG emissions are sourced from the EDGAR database Global Greenhouse Gas Emissions (Crippa, M. et al. 2024) and are allocated across the NEMESIS-World sectors based first on the corresponding sector, and second, on the energy quantities, weighted by average emission factors.

2.5 Other data

The model also requires additional variables that are not included in the previously mentioned dataset, such as population by age and level of qualification, unemployment rate, and interest rates. The latter two are sourced from (OECD 2025). Population data is taken from KC et al. (2024), which provides demographic information by age group, following the classification used in NEMESIS-World: [0-15[; [15-25[; [25-55[; [55-65[; [65-75[; [75+]. Additionally, this dataset includes information on qualification levels, which is essential for calibrating labour supply by education level in the model.

3 Theoretical aspects and detailed modelling features

3.1 General structure

The model is structured around several interconnected blocks (Figure 5).

It starts with households**,** whose income—composed of labour and capital earnings and adjusted for taxes and transfers from or to the government—determines both the level and composition of final consumption.

On the other side, the government collects taxes and provides support to households and firms through social benefits and subsidies. The government also directly demands products and services from various economic sectors.

Household and government final consumption, combined with intermediate consumption and investment goods demanded by other economic sectors, constitute the domestic demand addressed to domestic firms. Adding exports leads to the total demand faced by the domestic economy.

In response to this total demand, domestic firms decide whether to meet it through domestic production or imports. In the case of imports, the product or service imported from one region corresponds to the exports of the supplying region.

For the share of demand covered by domestic production, the production process requires intermediate consumption from other sectors, capital (or investments accounting for net of installed capital and obsolescence), and labour. All production factors are remunerated at market prices: intermediate and investment goods are paid at production prices plus margins, while labour is paid through wages.

Wage formation depends on the labour demand from firms, differentiated by qualification levels, and on the labour supply, which results from the population structure in terms of age and education, but also on the tension on the labour market, proxied by the unemployment rate by educational level. Labour supply is exogenous in the model.

Domestic production of goods and services requires, among other inputs, energy—part of which comes from fossil fuel sources. The use of fossil energy leads to GHG emissions into the atmosphere. Household consumption, particularly for heating, cooling, and private transportation, also involves fossil energy use and therefore contributes to GHG emissions. Additionally, some specific production processes directly generate GHG emissions into the air.

In the current version, the interest rates as well as the exchange rates are exogeneous variables.

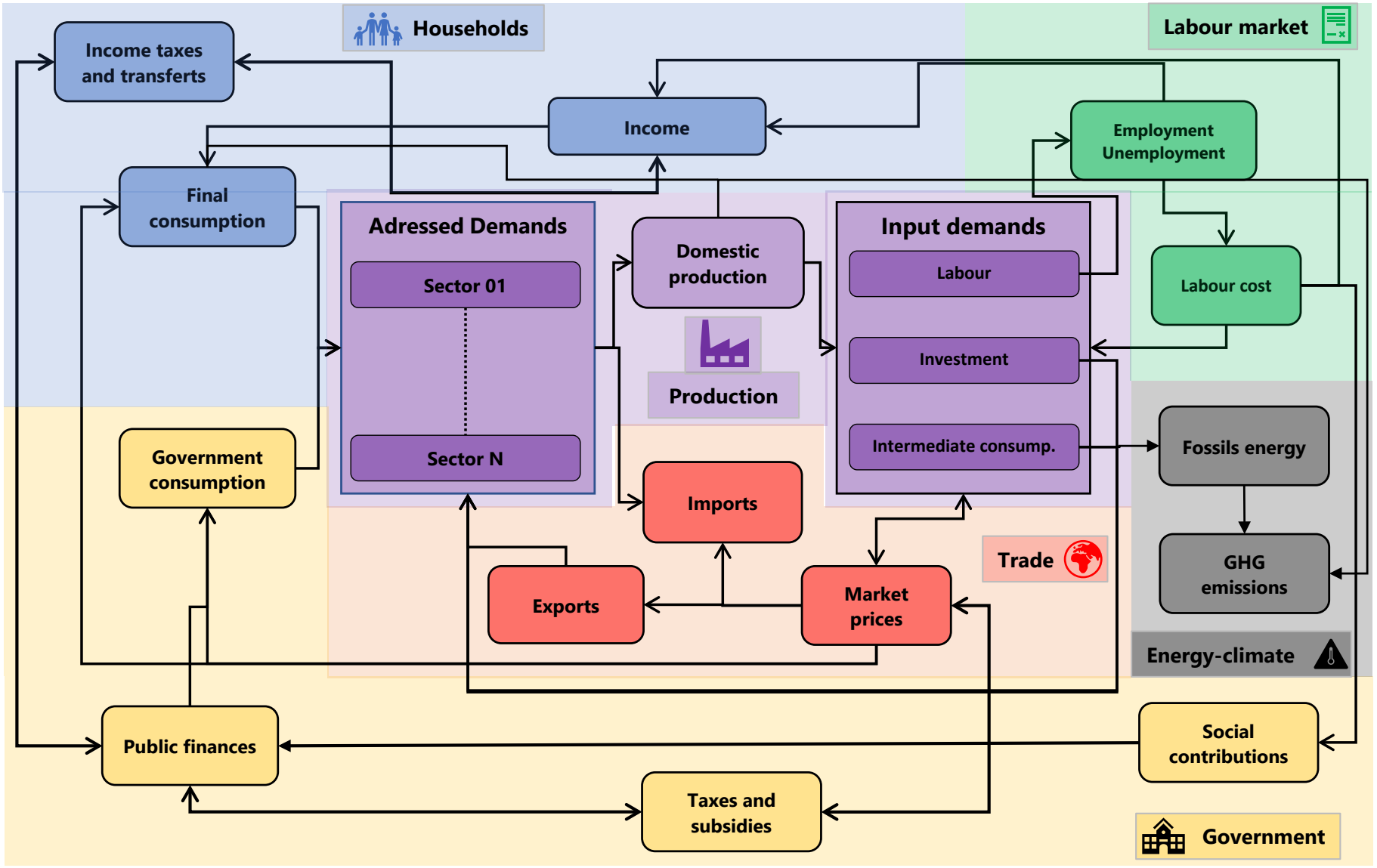


Figure 5. NEMESIS-World general scheme

3.2 Supply side

On the supply side, each sector in each region is faced with total demand, which is composed of households' and government's final consumption, as well as demand from other firms for intermediate consumption and investment goods and finally of the demand outside the region, i.e., exports.

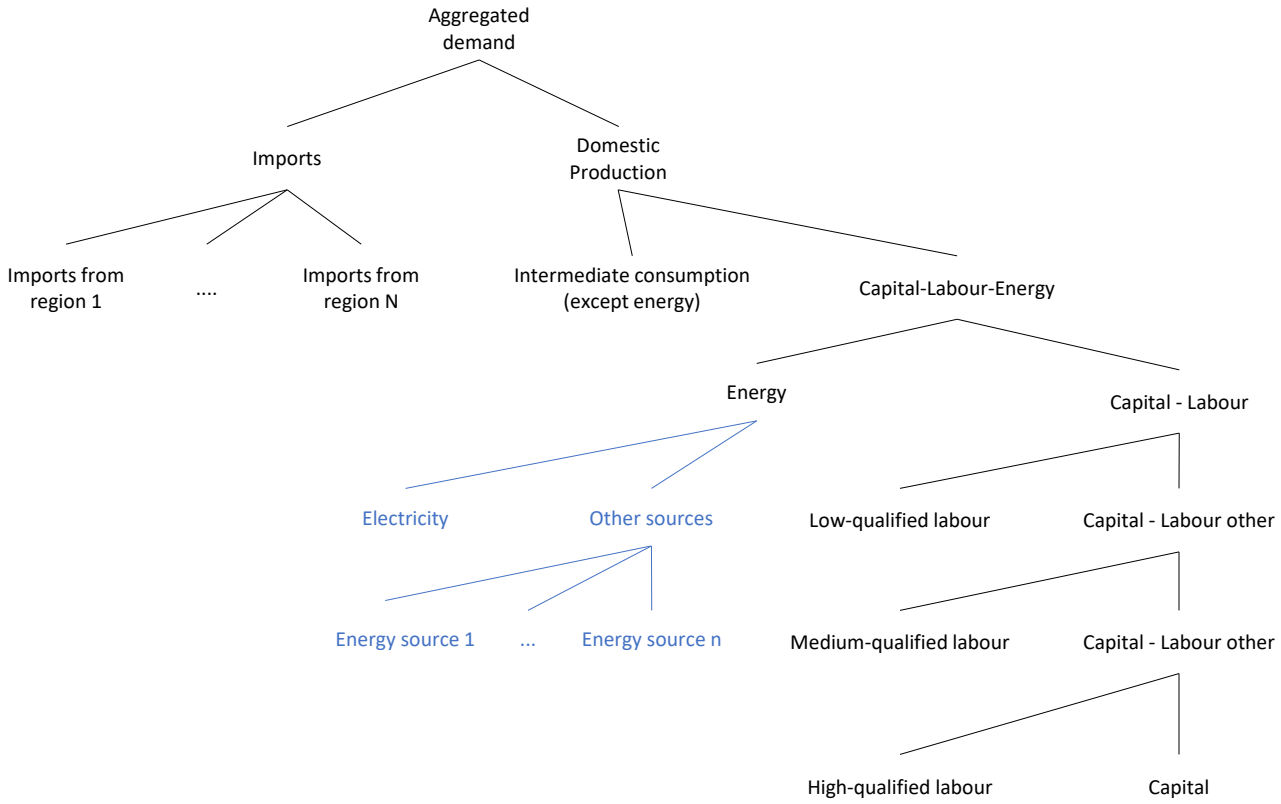


Figure 6. Production function nested structure

In the first step, sectors decide—via Armington functions—whether to meet this demand through imports or domestic production, based on relative prices and preferences for domestic products or services (equations 7 and 8 in section 4.4).

Once the level of domestic production is determined, the sector gradually defines the quantity of production factors to mobilise. The production process is modelled using nested CES production functions (equations 1 and 2).

At the first level, the choice is between intermediate consumption (excluding energy) and a combined capital-labour-energy bundle. In the second step, energy is separated from this bundle. The energy demand is then split into electricity and other energy sources, and finally into specific energy types within the non-electricity category.

On the capital-labour side, the next three stages separate labour demand by qualification level: first low-skilled workers, then medium-skilled, and finally high-skilled workers.

$$Bdl_i = \propto_{Bld_i} . \left(Bdl_{up} . TPBdl_{up}\right) . \beta_{Bld_i} . \left(P_{Bdl_i} . TPBdl_i\right)^{-\sigma_{Bdl_{up}}} . \left(\sum_i^N \beta_{Bld_i} . \left(P_{Bdl_i} . TPBdl_i\right)^{1-\sigma_{Bdl_{up}}}\right)^{\frac{\sigma_{Bdl_{up}}}{1-\sigma_{Bdl_{up}}}} \quad (1)$$

$$\mathrm{PBdl}_{up} = \propto_{PBld_{up}} \cdot \left(\sum_{i}^{N} \beta_{Bld_i} \cdot \left(P_{Bdl_i} . TPBdl_i \right)^{1-\sigma_{Bdl_{up}}} \right)^{\frac{1}{1-\sigma_{Bdl_{up}}}} \quad (2)$$

With, Bdl_i, the ith element of the bundle of the N elements in Bdl_{up}, the upper element of the bundle, $TPBdl_i$, the efficiency factor of the ith bundle, P_{Bdl_i}, the price of the ith bundle, the efficiency factor of the bundle i, β_{Bld_i}, the cost share of the ith bundle, $\propto_{Bld_i}$, a scale parameter and $\sigma_{Bdl_{up}}$, the substitution elasticity.

In this supply-side framework, the substitution parameters of the CES functions are key to determining how the supply block responds to price shocks. Since the data used in the model are not time-series, we cannot estimate these parameters directly by sector or region.

Therefore, we conducted a literature review of existing estimates of CES substitution elasticities across different industries. Figure 7 summarises the main findings. Based on this review, we retained the average elasticity values for each aggregated sector.

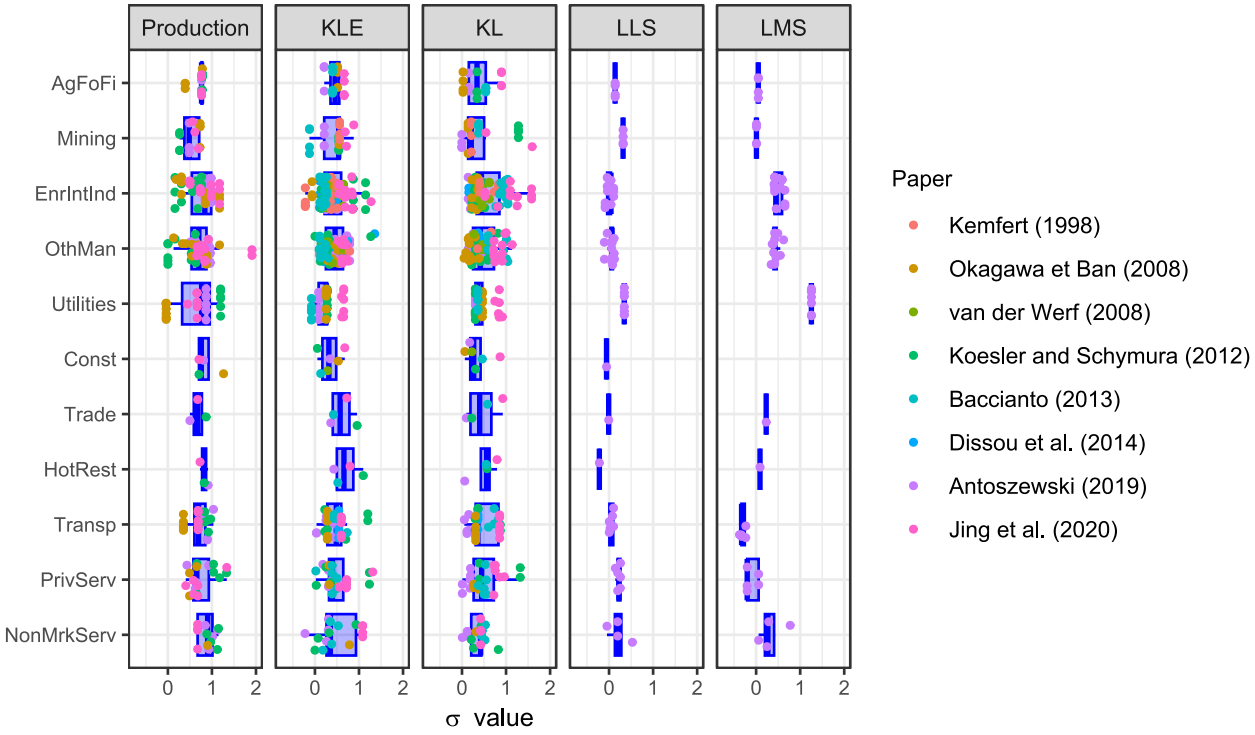


Figure 7. Literature review summary results for CES substitution elasticity by industry and bundle

Source: Kemfert 1998; Okagawa, Azusa et Ban, Kanemi 2028; Van Der Werf 2007; Koesler et Schymura 2015; Baccianti 2013; Dissou et al. 2015; Antoszewski 2019; Cao et al. 2020

NB: Values above 2 have been removed from the figure.

Naming convention: AgFoFi: Agriculture, Forestry and Fishery, Mining: Mining and Quarrying, EnrIntInd: Energy intensive Industry, OthMan: Other manufactures, Utilities: Utilities, Const: Construction, Trade: Trade, Hotrest: Hotels and Restaurants, Transp; Transports, PrivServ: Market services; NonMarkServ: Non-Market services. Bundles: KLE: Capital-Labour-Energy; KL: Capital-Labour; LLS: Low-skilled-other labour; LMS; medium skill-other labour

3.3 Households' consumption

The trade-off between consumption and savings depends on the real disposable income, the aggregated household consumption price index, the unemployment rate, and the population structure—particularly the shares of young individuals (under 15) and older individuals (over 65).

This relationship is modelled using an Error Correction Model (ECM) following Engle and Granger (1987), which captures both short-term and long-term dynamics. Shocks can have different impacts in the short run versus the long run, but over time, all shocks tend to converge towards the long-term relationship.

The long-term relationship is specified as follows:

$$\ln(c) = \beta_r + \beta_{rev}.\ln(rev) + \beta_{yg}.Sh_{young} + \beta_{old}.Sh_{old} + \beta_{infl}.ln(infl) + \beta_U.U + \beta_{popact}.Sh_{popact} \quad (3)$$

The short-term dynamic is specified as:

$$dln(c) = \alpha_r + \alpha_{rev}.dln(rev) + \alpha_{yg}.dSh_{young}, + \alpha_{old}.dSh_{old} + \alpha_{infl}.d\,ln(infl) + \alpha_U.dU + \alpha_{popact}.dSh_{popact} + \alpha_{err_lt}.error_lt \quad (4)$$

Where:

- c: per capita final household consumption
- rev: per capita household disposable income
- Sh_{young}: share of the population younger than 15
- Sh_{old}: share of the population older than 65
- Sh_{popact}: share of the active population
- $infl$: inflation
- U: unemployment rate
- $error_lt$: the estimation errors of the long-term relationship.

In equation (3), the consumption per capita is a positive function of the households' disposable income (with a unitary indexation in the long-term), a negative function of consumption prices and of unemployment rate that proxies the uncertainty of the current domestic economic context, the share of young, old and active population may also influence positively or negatively the households consumption.

These relationships have been estimated for a sample of countries (China, USA, UK, Germany, France, Spain, Italy, Japan, Canada, South Korea, Brazil, Russia, Australia, Mexico, India, and Indonesia) and years (from 2000 to 2022), based on data drawing from OECD (2024c).

Once total household consumption expenditure is determined, households allocate their consumption across different products and services. This allocation is modelled using a nested CES function (see Figure 8).

At the first level, aggregate final consumption is divided into four main nodes: "*Basics*", "*Transportation*", "*Trade*", and other goods and services (referred to as "*Rest*"). Trade is modelled as a fixed share of certain consumption products, assuming a constant average margin rate.

The "*Basics*" bundle is further disaggregated into three sub-nodes: "*Essentials*", "*Housing*", and "*Heating and Cooling*". These are subsequently split into:

- Essentials: "*Food*" and "*Clothing*".
- Housing: "*Rent*" and "*Water and Waste*".
- Heating and Cooling: different types of fuels.

On the "*Transportation*" side, the next level distinguishes between "*Private Cars*", "*Other Inland Transport*", "*Air Transport*", "*Water Transport*" and "*Other Transport*". "*Private Cars*" are then split into "*Internal Combustion Engine Vehicles*", "*Plug-in Hybrid Electric Vehicles*", and "*Battery Electric Vehicles*", each of which is further divided into vehicle purchase and the respective fuel consumption.

For the "*Rest*" category (i.e., the remaining goods and services not yet allocated), the next step distinguishes between "*Non-Market Services*" and a residual "*Rest*" node. "*Non-Market Services*" are then broken down into "*Education*", "*Health*", and "*Other Non-Market Services*". The "*Rest*" bundle is split into "*Leisure*", "Equipment", and a residual "*Rest*" category. Finally, "*Leisure*" is further disaggregated into "*Hotels and Restaurants*", "*Information and Communication*", and "*Other Leisure*" services.

All final nodes in the consumption tree are linked to the corresponding economic sectors, representing the demand addressed by households to each sector (see Table 15).

$$Cons_{node_i} = \propto_{node_i} . Cons_{node_{up}} . \left(\frac{P_{node_{up}}}{P_{node_i}} \right)^{\sigma_{node_{up}}} \quad (5)$$

$$P_{node_{up}} = \propto_{P_{node_i}} . \left(\sum_{i}^{N} \beta_{Cons_{node_i}} . {P_{node_i}}^{\sigma_{node_{up}}} \right)^{1/1-\sigma_{node_{up}}} \quad (6)$$

Where, $Cons_{node_i}$, the consumption demand for the node i, the $P_{node_{up}}$, the price of this upper node, $Cons_{node_{up}}$, the consumption demand for the upper node and $P_{node_{up}}$, its price, $\beta_{Cons_{node_i}}$, the share of the consumption demand in the node, $\propto_{P_{node_i}}$, scale parameters, and $\sigma_{node_{up}}$ the substitution elasticity.

The substitution elasticities in the nested CES household consumption function range between 0.3 and 1. A dedicated survey was conducted to collect data enabling the differentiation of these elasticities across the nesting levels. However, the results proved to be neither consistent nor sufficiently robust. Consequently, we adopted conventional values commonly used in large-scale models (e.g., GTAP). These estimates can be revised once more reliable data become available.

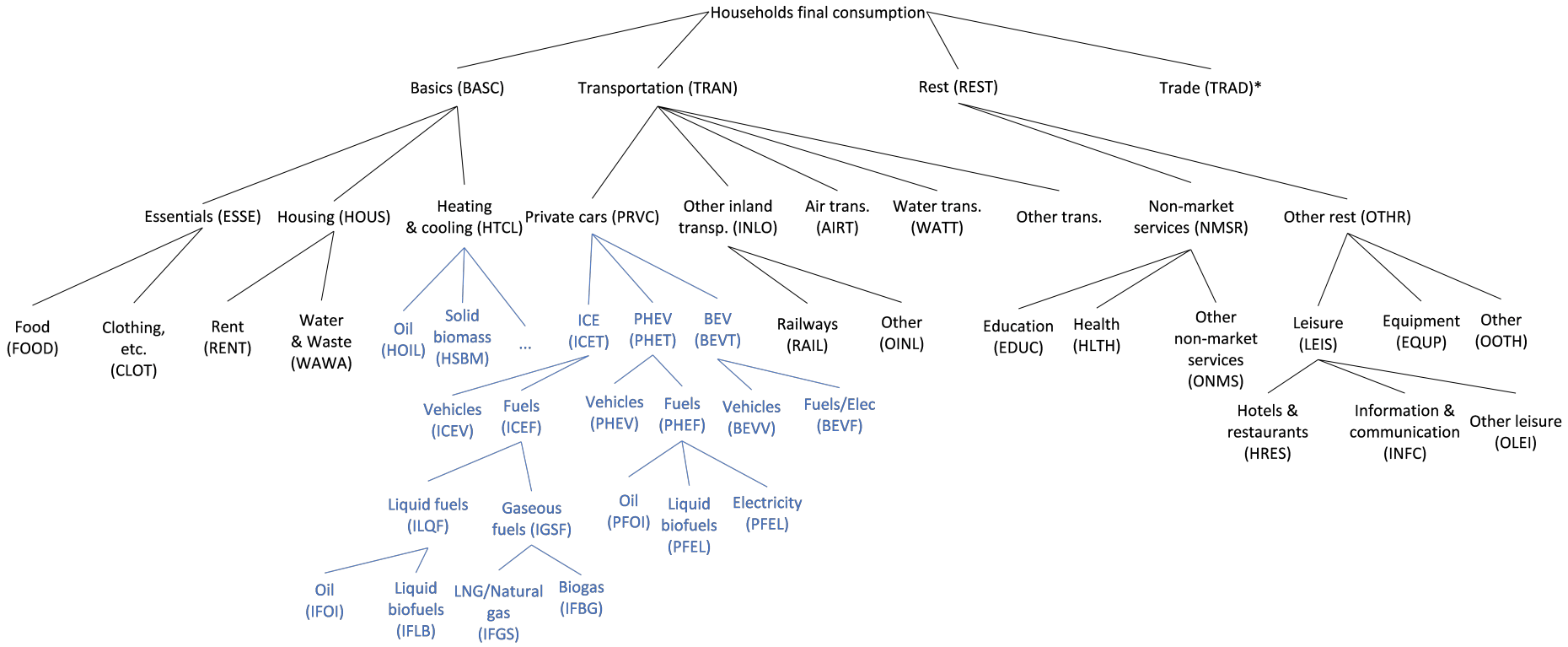


Figure 8. Households' consumption nested structure

**: Trade is modelled as a fixed share of households' consumption of products*

Code in brackets are code name used in the model

3.4 International Trade

International trade is integrated in the nested CES production functions, following the Armington approach (Armington 1969). As illustrated in Section 4.2 and Figure 6, trade at the sectoral level is represented in two steps. First, the representative firms in each sector decide how to satisfy demand, choosing between domestic production and imports. The Armington framework allows for a combination of both options (see equations 7 and 8).

$$DOMQ = \propto_{DOMQ} . ADDDTOTQ . {\beta_{DMOQ}}^{\sigma_{imp}} . \left(\frac{PPROD}{PADDDTOT}\right)^{-\sigma_{imp}} \quad (7)$$

$$IMPQ = \propto_{IMPQ} . ADDDTOTQ . {\beta_{IMPQ}}^{\sigma_{imp}} . \left(\frac{PIMP}{PADDDTOT}\right)^{-\sigma_{imp}} \quad (8)$$

Where, $DOMQ$, the domestically satisfied demand, $IMPQ$ the imports, $ADDDTOTQ$, the total demand addressed, $PPROD$, the domestic production price, $PIMP$, the price of imports, $PADDDTOT$, the price of the internal demand, $\propto$, scale parameters, β_x the share of the demand X in the bundle and σ_{imp} the substitution elasticity.

In the second step, the total volume of imports required to satisfy sectoral demand is allocated across different regions based on relative prices (see equations 9 and 10). Since imports are modelled bilaterally, the exports of one region correspond to the imports of another. The substitution elasticity values for the first level of the CES function ranges between 2.5 and 3.1 and are based on (Bajzik et al. 2020) and those of the second level range between 0.5 and 3.8 (Donnelly et al. 2004).

$$PIMP = \propto_{PIMP} . \sum_{r \neq d}^{R} {\beta^r_{IMPQ_{bilat}}}^{\sigma_{bilat}} (PIMP^r_{bilat} . iceb^r)^{(1-\sigma_{bilat})} \quad (9)$$

$$IMPQ^r_{bilat} = \propto_{IMPQ_{bilat}} . IMPQ . {\beta^r_{IMPQ_{bilat}}}^{\sigma_{bilat}} . \left(\frac{PIMP^r_{bilat} . iceb^r}{PIMP}\right)^{-\sigma_{bilat}} \quad (10)$$

Where $PIMP$, the price of import in region d, $PIMP_{bilat}$, the import prices of the product coming from region r (i.e. the export price for the country r including import taxes), $IMPQ^r_{bilat}$, the import of the region d from region r, $iceb^r$, the "iceberg cost" (Krugman 1991), $\propto_{PIMP}$, a scale parameter and $\beta^r_{IMPQ_{bilat}}$, the share of imports from region r in the overall imports. The iceberg costs are calculated as coefficients ranging between 1 and 2 and scaled with the distance between the capital of each region.

3.5 Labour market

While labour demand is derived from the optimisation behaviour inherent in the firms' use of the production functions (see Figure 6), labour supply is based on population projections by qualification level (educational attainment) and age. In the current version of the model, the projection of the qualification is based on KC et al. (2024), and in particular the one for SSP2. The interaction of labour demand and supply is specified in the model by wage curves. These wage curves determine the wage rates by linking the rate of growth of wages to unemployment level, labour productivity (to ensure long term stability of profits/total wages ratio) and consumption prices (equation 11). Wage equations are different for low-, medium- and high-qualified labour, essentially constituting three different labour markets.

$$Av = \propto_{av} . \left(\frac{PRODQ}{DEMPTOT}\right)^{\theta_{pty}} . PCONS^{\theta_{pons}} . PCONS_{-1}^{\theta_{pcons-1}} . e^{(\theta_{un} . (UNEMPRA - UNEMPRA^{LT})} \quad (11)$$

Where, Av, the average annual earnings by workers, $PRODQ$, the production, $DEMPTOT$, the total employment, PCONS, the consumption price at time t and $t-1$, $UNEMPRA$, the unemployment rate,

$UNEMPRA$, the natural employment rate (long-term employment rate that does not accelerate inflation) not $\propto_{av}$, a scale parameter, θ_{pty} the productivity parameters (set to 0.66, proxying the share of labour in GDP), θ_{pons} and $\theta_{pcons_{-1}}$, indexation parameters of wages on consumption prices (both set to 0.5) and θ_{un}, the unemployment parameter (sets to -1.5).

3.6 Energy and climate module

The supply and consumption blocks, through the CES embodied production (Figure 6) and the consumption by purpose functions (Figure 8), define the energy demand by product (see equation 1 in section 4.2 and 5 in section 4.3). These product-specific energy demands are then allocated to their corresponding supplying sectors.

The main feature of the energy module lies in modelling the power generation sector. In this sector, 17 distinct technologies are specified (see Table 9 for an indicative example of the "Rest of EU" region) each characterized by different parameters: investment costs, fixed and variable operation and maintenance costs, fuel costs, and CO_2 emission costs. These parameters are used to calculate the levelized cost of electricity (LCOE) for each technology. The resulting LCOEs are then introduced into a logistic function, which determines the share of each technology in the overall power generation mix (equation 12). Underlying parameters can be adapted based on harmonisation protocols depending on the scope of each scenario analysis, harmonising this set of parameters with OMINIA is also envisage.

Table 9. *Power generation parameters (illustrative case of 2030 for "Rest of EU" region)*

	Overnight investments cost (€2019/kW in 2030)	Fixed O&M cost (€2019/kW in 2030)	Variable O&M cost (€2019/MWh in 2030)	Effective capacity factor (% in 2030)	Technical capacity factor (% in 2030)	Net conversion efficiency (% in 2030)	Lifetime (years)	Construction time (years)
Nuclear	3 853	122	7.9	0.75	0.85	0.38	50	8.0
Coal	1 511	38	3.7	0.60	0.80	0.46	40	3.0
Coal (CCUS)*	3 629	69	6.4	0.50	0.80	0.29	40	5.0
Gas	755	21	2.5	0.35	0.35	0.57	30	3.0
Gas (CCUS) *	1 931	45	3.5	0.30	0.80	0.46	30	5.0
Oil	1 273	22	2.9	0.40	0.40	0.35	40	1.0
Biomass (wastes)	2 136	47	0.9	0.60	0.10	0.34	20	3.0
Biomass (biogas)	1 208	26	2.7	0.60	0.20	0.38	25	2.0
Biomass	2 069	43	3.8	0.60	0.80	0.50	40	3.0
Biomass (CCUS) *	3 820	24	2.9	0.50	0.70	0.43	30	5.0
Hydro	3 183	27	0.3	0.50	1.00	1.00	60	8.0
Geothermal	4 743	101	0.3	0.45	0.45	0.30	30	4.0
Solar PV	363	13	0.0	0.17	0.17	1.00	20	1.5
CSP	4 032	105	0.1	0.26	0.26	0.33	25	2.5
Wind Onshore	1 171	19	0.5	0.26	0.26	1.00	25	1.5
Wind Offshore	1722	35	0.5	0.39	0.39	1.00	25	2.5
Tidal	5093	128	0.1	0.27	0.27	1.00	80	5.0

Source: Authors calculation based on IEA (2024), Mantzos, et al. (2019) and UNData (2025a).

NB: values differ overtime (except lifetime and construction time) and according to region.

**: CCS technologies are not available on production before 2035 in the model*

$$Prodp_{tech} = \left[\propto_{tech}.Prodp_{res}.\left(\frac{LCOE_{tech}}{LCOE_{Tot}}\right)^{\left(\emptyset_{tech}+\partial_{tech}.e^{\mu_{tech}.Sh_{tech-1}}\right)}\right].AJ_{elec} \quad (12)$$

With $Prodp_{tech}$, the production of electricity with the technology tec. The variable $Prodp_{res}$ represents electricity production from technologies whose deployment is not constrained. In some scenarios, certain

technologies are assumed to follow pre-defined (non-flexible) deployment pathways—nuclear power, for example, whose expansion is often governed by political decisions and national regulatory limits rather than purely economic considerations. $LCOE_{tech}$, is the levelized cost of the technology, $LCOE_{Tot}$, the levelized cost of all technologies (weighted with the power mix of previous period), Sh_{tech-1}, the share of the technology in the power generation mix of the previous period, AJ_{elec}, an adjustment variable ensuring that the sum of the all production means equal total demand, $\propto_{tech}$, scale parameters and $\emptyset_{tech}$, ∂_{tech} and μ_{tech}, the parameters of the logistic functions.

For GHG emissions, we distinguish four different gases (CO_2, CH_4, N_2O and F-gases) and 6 different emissions sectors: fuels combustion, fugitive emissions, industrial processes, agriculture, wastes and land use (this later is exogeneous). Emissions from fuel combustion and fugitive emissions are modelled based on emissions factors for each fossil fuel (solid fuel, oil and natural gas) and each gas (CO_2, CH_4 and N_2O, equation 13) whereas GHG emissions from industrial processes, agriculture and wastes are a function of the production of the emitting economic activities (equation 14). For the later, exogenous efficiency trends can be added as well as abatement factors according to emissions price (equation 15).

$$EM_F = \propto_{EM} \cdot \left[\sum_{FF} FF.emgas_{FF} \right] \tag{13}$$

$$EM_O = \propto_{EM} .PRODQ.TPT_{EM}.FACTABT_{EM_O} \tag{14}$$

$$FACTABT_{EM_O} = \frac{\emptyset_{EM}}{\partial_{EM}.(\delta_{EM}.TAX_{EM})^{\theta_{EM}}} \tag{15}$$

With EM_F, the emissions from fuel combustion or fugitive emissions, FF, the quantity of fossil fuels in physical unit, $emgas_{FF}$, the emission factor depending of the gas and the fossil fuel and $\propto_{EM}$, a scale parameter. EM_O is emissions from industrial processes, agriculture and wastes, $PRODQ$, the production of the emitting economic activity, TPT_{EM}, the efficiency factor, $FACTABT_{EM_O}$, the abatement factor, TAX_{EM}: the tax on the emissions and $\emptyset_{EM}$, ∂_{EM}, δ_{EM}, θ_{EM} parameters for the abatement curves.

4 Evaluating the model's response to shocks

Here, we present a set of indicative tests performed with the final version of the model to ensure that it responds as expects to external input. The first test focuses on evaluating the model block by block independently without inter-linkages, allowing us to verify and assess the main properties and first order effects of each block without feedback loops that could potentially blur the identification of errors. In the second test, we proceed to evaluate the complete model results by performing benchmark simulations using diagnostic runs as established by Kriegler et al. (2015) based on simple carbon price paths. Given the simplicity of the tests performed this preliminary diagnostics test performed aims to ensure that the model responds to simple policy shocks, before proceeding to the more updated diagnostics protocol, followed in D6.7.

4.1 Testing the model block by block

In order to ensure that the model reacts properly and does not diverge from expected outcomes—or at least to understand the reasons it does and plan calibration activities— a set of tests have been conducted. The model needs to be tested block by block, introducing specific shocks in each block without fully linking all components. In Table 10, we list the set of shocks performed on this final version of the model.

These shocks are introduced on a flat no-policy baseline scenario, i.e., a scenario where all variables (e.g. GDP, population, etc.) are assumed to remain constant over time. We then compare the results from the simulation based on shocks with this baseline scenario to assess the impact of the shocks on main variables of each respective block.

Table 10. List of shocks introduced in the model block by block

Supply side	+20% of wages of workers with lower qualifications in Mexico from 2025 to 2050 +1ppt of real interest rate in Italy from 2025 to 2050 +100% of energy final energy price in Japan from 2025 to 2050
Households' aggregated consumption	+10% of households' real disposable income in USA from 2020 to 2050
Households' consumption allocation	+50% of refined oil prices in USA from 2025 to 2050 +20% of price in food industry in USA from 2025 to 2050
Trade	+10% of domestic production prices for all sectors in China from 2025 to 2050
Power generation	+100€/tCO_2 in all regions from 2025 to 2050

4.1.1 Supply block

4.1.1.1 Increase of 20% of the wages of workers with lower qualifications in Mexico from 2025 to 2050

Figure 9 illustrates the variation in production factor demands following a 20% wage increase for low-skilled workers in Mexico. The rise in low-skilled wages induces a reduction in their demand, ranging from approximately 7% to less than 1%, depending on the sector. These heterogeneous responses reflect differences in substitution elasticities across sectors. For example, sectors characterised by high elasticity values—such as utilities—exhibit the largest declines (around –6%), whereas those with low elasticities, such as the chemical industry, show almost no adjustment in demand. The effects on other production factors similarly depend on the degree of substitutability. In sectors such as "*59 – Other service activities*" or "*41 – Construction*" where substitution elasticities are high across various levels of the production bundles, the demand for other employment qualification levels also experiences a pronounced decline. Overall, different

types of employment and capital appear to be complementary, while energy and other intermediate inputs act as substitutes.

As expected, when the cost of low-skilled labour increases, the model reduces the demand for this category of workers. Depending on the degree of substitutability or complementarity with other inputs—particularly other types of labour—the demand for these alternative inputs may either rise or fall. Because the shock is introduced only on the supply side of the model, several counteracting mechanisms are not captured here. On the one hand, if real wages also rise, households' real disposable income increases, boosting their demand for domestically produced goods and services as well as for imports—potentially to an even greater extent for imported goods, since domestic production prices are expected to rise following the wage increase. On the other hand, the resulting destruction of employment raises the unemployment rate, which tends to exert downward pressure on real wages and reduces household consumption in response to deteriorating labour-market conditions.

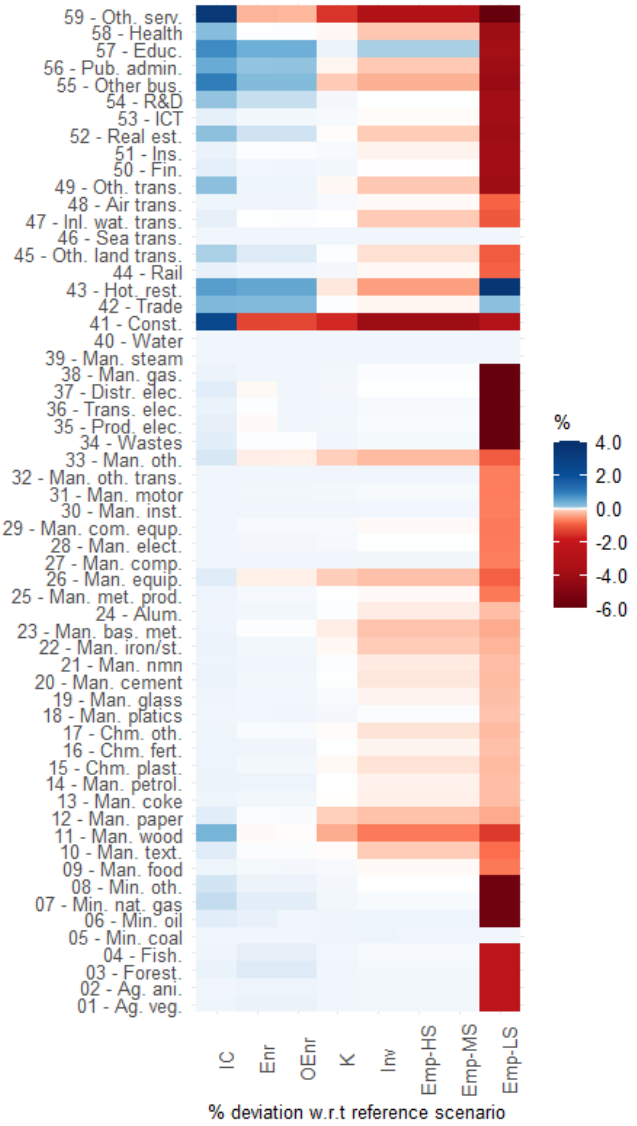


Figure 9. Sector production factors deviation after an increase of 20% of low-qualified workers in Mexico in 2030

Note: IC: Intermediate consumption excluding energy, Enr: energy consumption, OEnr: energy consumption except electricity, K: capital stock, Inv: gross fixed capital formation, Emp-HS: high-qualified employment, Emp-MS: medium-qualified employment, Emp-LS: low-qualified employment.

4.1.1.2 +1ppt of real interest rate in Italy from 2025 to 2050

The introduction of a one–percentage-point (ppt) increase in the real interest rate in Italy within the supply block leads to a significant reduction in investment demand and in the capital stock (Figure 10). These declines range from –7.3% to –3.6% for investment (gross fixed capital formation) and from –2.6% to –0.5% for the capital stock, five years after the shock. Overall, the rise in the cost of capital exerts a moderate effect on other production factors, except in a few specific cases, where a slight substitution occurs with labour demand by qualification level and with intermediate consumption, including energy inputs.

These results are consistent with the expected reaction of the model to an increase in the cost of capital. Higher interest rates raise the user cost of capital, which reduces the expected return on future investments and therefore depresses investment demand. As investment declines, the capital stock naturally contracts. Since interest rates are exogenous in the model, the decrease in demand for capital goods cannot offset the rise in interest rates, even in the fully specified version of the model.

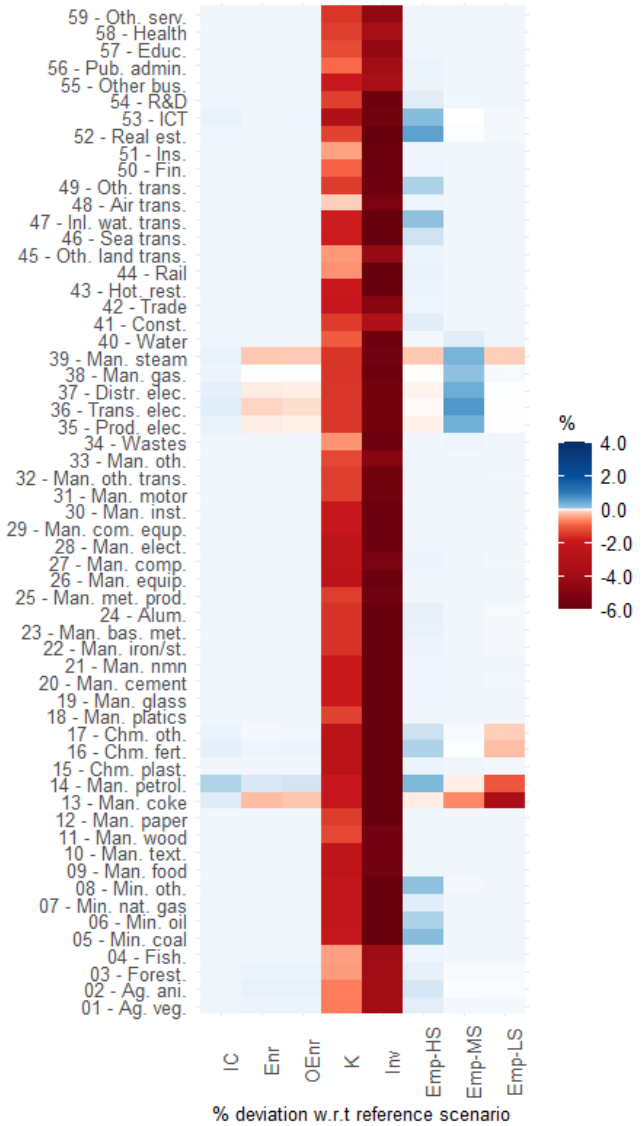


Figure 10. Sector production factors deviation after an increase of 1 ppt of real interest rate in Italy in 2030

Note: IC: Intermediate consumption excluding energy, Enr: energy consumption, OEnr: energy consumption except electricity, K: capital stock, Inv: gross fixed capital formation, Emp-HS: high-qualified employment, Emp-MS: medium-qualified employment, Emp-LS: low-qualified employment.

4.1.1.3 +100% increase of energy price in Japan from 2025 to 2050

The final shock introduced in the supply block is a doubling of final energy price (all energy products combined) in Japan (Figure 11). The results indicate a substantial reduction in the demand for energy products, on the order of 60% in the agricultural, forestry, and fishing sectors (01 to 04), and a smaller decline in sectors such as utilities. Following this energy price shock, labour demand by qualification level and capital investment tend to moderately increase, although in some sectors they slightly decrease as the high- and medium-qualified workers in the "Manufacture of motor vehicles, trailers and semi-trailers" or in the "Manufacture of food, beverage and tobacco" sectors . Similarly, but to a smaller extent, intermediate consumption rises, substituting for the reduction in energy demand.

Once again, these results are consistent with our expectations, indicating that—at least in broad terms—the model, and specifically its supply block, responds appropriately to a shock in final energy prices. Energy demand decreases, with a relatively high elasticity, suggesting that the model should react reasonably well to a carbon price. This holds even though, in this case, the price increase applies to the overall energy input and not solely to fossil fuels.

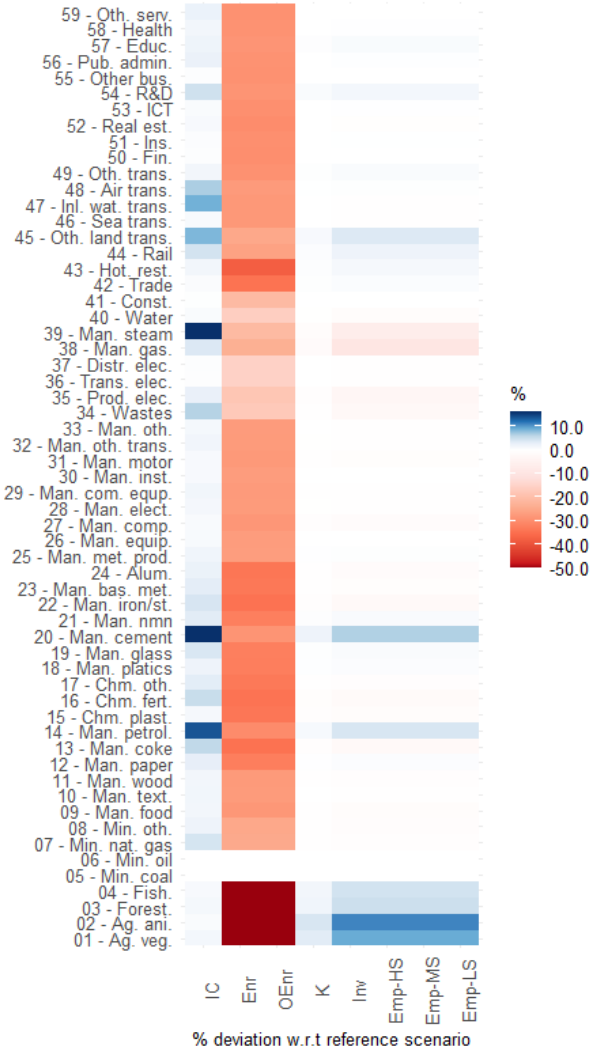


Figure 11. Sector production factors deviation after an increase of 100% of energy price in Japan in 2030

Note: IC: Intermediate consumption excluding energy, Enr: energy consumption, OEnr: energy consumption except electricity, K: capital stock, Inv: gross fixed capital formation, Emp-HS: high-qualified employment, Emp-MS: medium-qualified employment, Emp-LS: low-qualified employment.

4.1.2 Households' aggregated consumption

Figure 12 illustrates the response of households' aggregated consumption in the USA due to a 10% increase in real disposable income in 2020. In the short term, households raise their consumption expenditures, but not proportionally to the income shock. In the year of the shock, i.e., 2020, total household consumption rise is limited at 2.9%, and consumption expenditures then grow gradually, reaching the full 10% increase in the long term. The average adjustment—defined as the point at which 50% of the shock is transmitted to consumption, here a 5% increase—occurs over two years, while ten years after the shock, i.e., in 2030, the adjustment reaches 98%.*

The response of aggregate consumption is fully consistent with the model's specification, which relies on an error-correction mechanism distinguishing between short-run and long-run dynamics. In the short run, households do not immediately consume all additional income; only about 30% of the extra revenue translates into higher consumption. Over time, however, their consumption gradually adjusts to the income shock, ensuring that the long-run saving rate remains constant. This pattern reflects the persistence of past behaviour—whether due to binding commitments or simple behavioural inertia—combined with gradual adjustment over time. The same logic applies to a negative income shock: in the short run, households would limit the decline in consumption by drawing on savings, but in the long run, their consumption would fully adjust to the lower level of income.

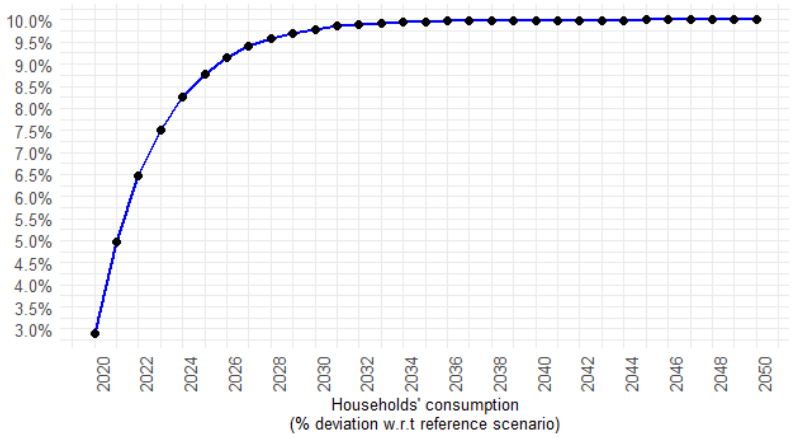


Figure 12. US households' consumption variations after a shock of 10% of real income

4.1.3 Households' consumption allocation

4.1.3.1 +50% of refined oil prices in USA from 2025 to 2050

Figure 13 presents the variations across different categories of households' consumption following a 50% increase in the oil price in the United States. Expenditures directly related to oil consumption show a sharp decline: for instance, oil use for heating and cooling decreases by 23%, while the consumption of other fuels (electricity, natural gas, solid biomass, etc.) rises by approximately 2.5%. Similarly, spending on gasoline for private transportation using internal combustion vehicles also falls significantly, by 19%, accompanied by a 10% decrease in purchases of such vehicles. Conversely, households increase their purchases of electric vehicles by about 4%.

The response of the consumption block to an oil fuel price shock in the United States is robust. Demand for this fossil energy and oil-intensive goods—particularly internal combustion engine vehicles—declines, with the strongest adjustment occurring for oil itself. Conversely, demand for alternative solutions, such as

battery electric vehicles for transport or alternative fuels for heating and cooling, increases. However, a negative oil price shock would also reduce households' income and therefore depress all categories of consumption—an effect that is not captured here, since for the purpose of this analytical test we assume that household income remains constant.

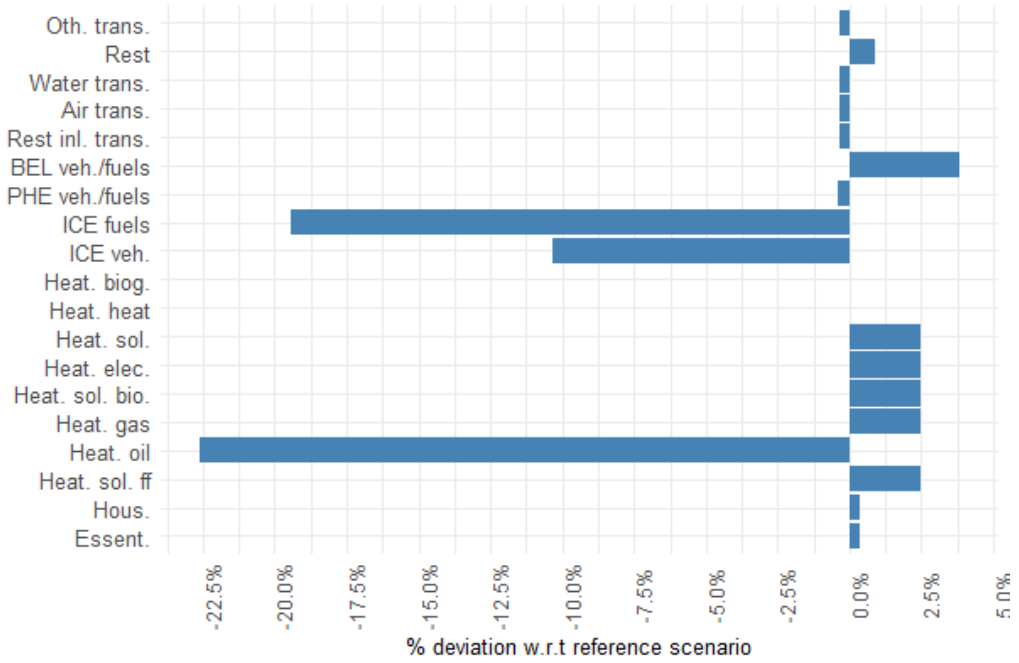


Figure 13. Variations of households' consumption by purpose after an increase of 50% of refined oil prices in USA in 2030

4.1.3.2 +20% of price in food industry in USA from 2025 to 2050

Similarly, Figure 14 shows the variations in the consumption categories "food", "clothes", "housing", "heating and cooling", "transport", and "rest" following a 20% increase in food industry prices in the United States. This price increase leads to a 3% decline in expenditures on "food" and "clothes," representing a relatively modest reduction compared with the magnitude of the price rise. Consumption related to "housing" and "heating and cooling" also decreases by about 1%, while spending on "transport" and other consumption items tends to increase slightly, by around 0.75%.

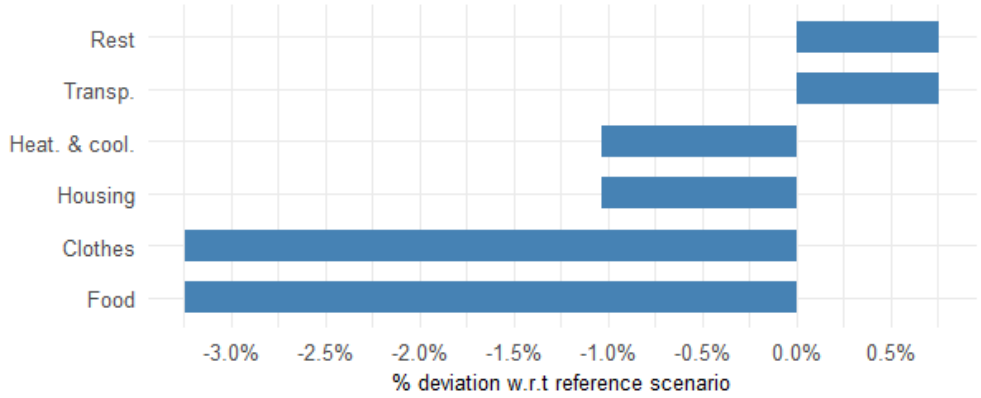


Figure 14. Variations of households' consumption by purpose after an increase of 20% of food industry prices in USA in 2030

4.1.4 Trade block

The introduction of a 10% shock to domestic production prices across all sectors in China results in moderate variations in domestic demand in relative terms, as for a majority of sectors, imports represents a small part of the total demand. In contrast, imports increase sharply, by approximately 30%, while exports decline significantly, ranging from 5% to 20% (Figure 15).

Thus, the model responds properly to an increase of the production price in China. Chinese domestic products and services are more expensive, as such a larger part of the total demand is satisfied by imports in substitution to domestic production whereas, commercial partners also decrease their demand of Chinese goods and services, leading to a decile of the Chinese exports.

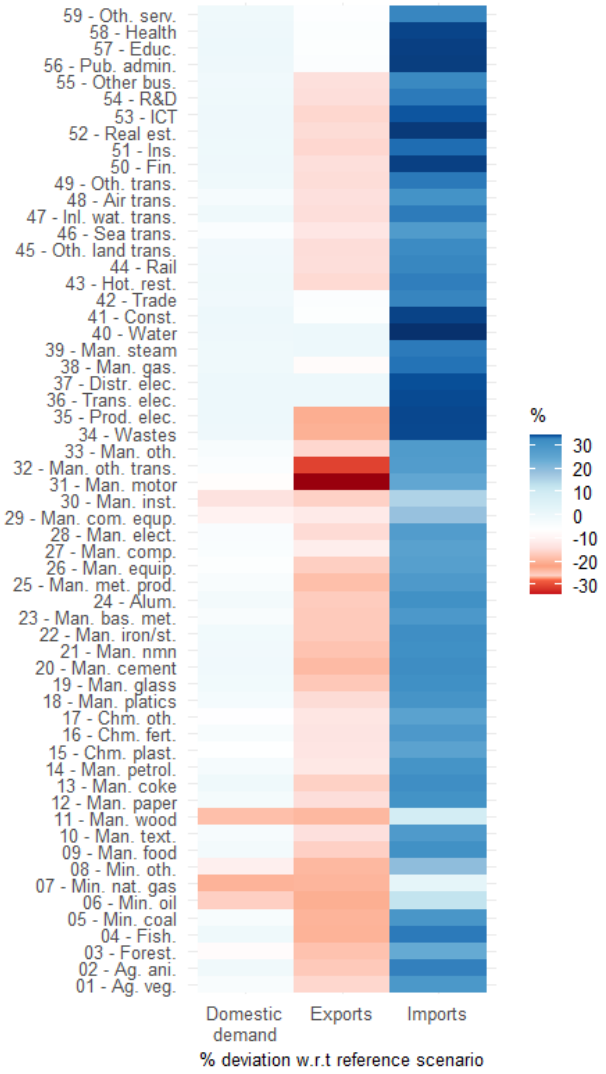


Figure 15. Deviation by sector of domestic demand, imports and exports after an increase of 10% of production price in China in 2030

4.1.5 Power generation

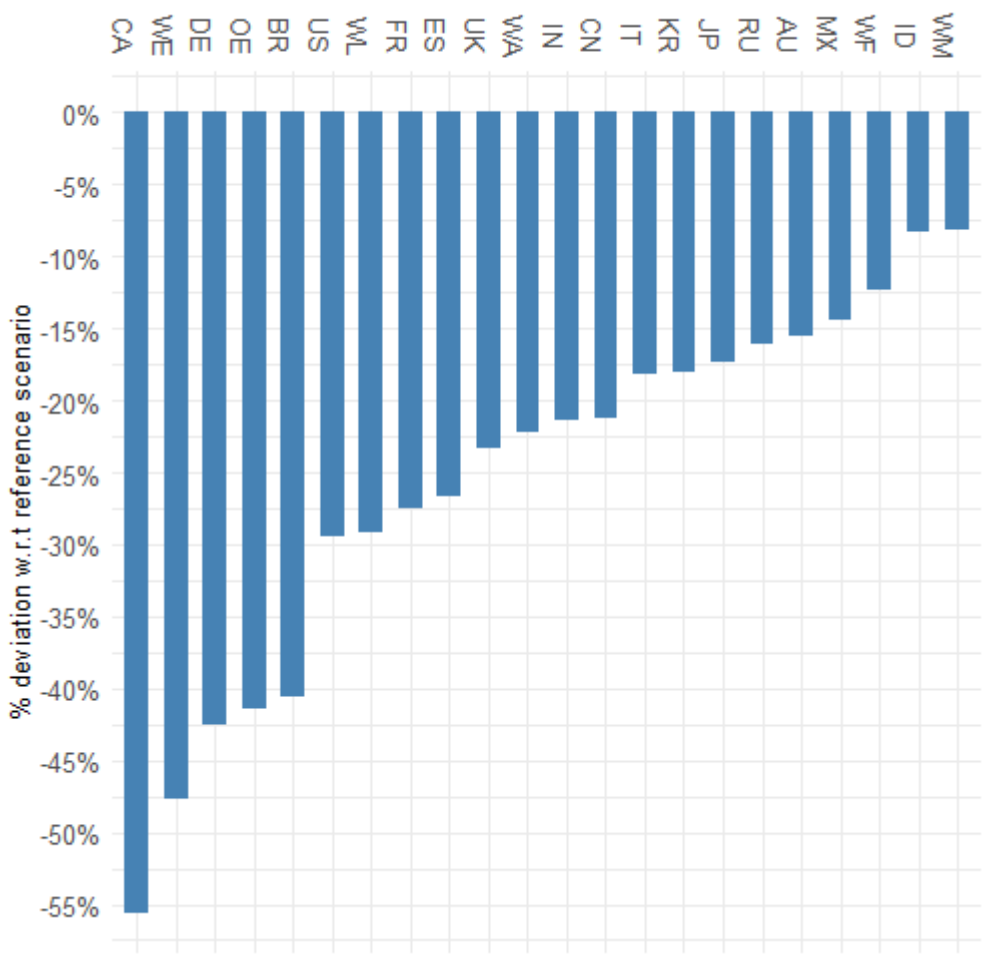


Figure 16. Deviation of CO_2 emissions in power generation after the implementation of a carbon tax of 100€/tCO_2 in 2030 in all countries

The implementation of a carbon tax of €100/tCO_2 in the power generation sector across all regions leads to a substantial reduction in sectoral CO_2 emissions. These reductions reach up to 55% in Canada, 48% in Germany, 30% in the United States, 17% in Japan, and 8% in Indonesia, with the latter presenting the most moderate decrease (Figure 16). Globally, the CO_2 emissions declines by 22% in the power generation, i.e. of about 2.5GtCO_2. The decline in emissions in the electricity sector results from a shift in the technologies used for power generation, with low-carbon technologies replacing fossil-fuel-based ones. Globally, the share of coal falls from 38% to 26%, that of gas remains stable around 22%, while wind power increases from 5% to 8% and solar energy from 3% to 5% (Figure 17).

Although it is evident that the model responds to the carbon tax by increasing decarbonisation efforts, the simplicity of a universal carbon tax leads to some counterintuitive results, such as an increase in the share of nuclear energy in Germany, despite longstanding efforts in the country towards the opposite direction. We should note that these tests serve primarily to test the responses of the model, rather than provide policy-relevant outcomes on their own. Contrary however, they highlight that efforts to increase the spatial granularity of NEMESIS, resulting in the implementation of NEMESIS-World, offers significant opportunities to model specific policies at the national level for most major economies, resulting in higher real-world relevance of the produced scenarios.

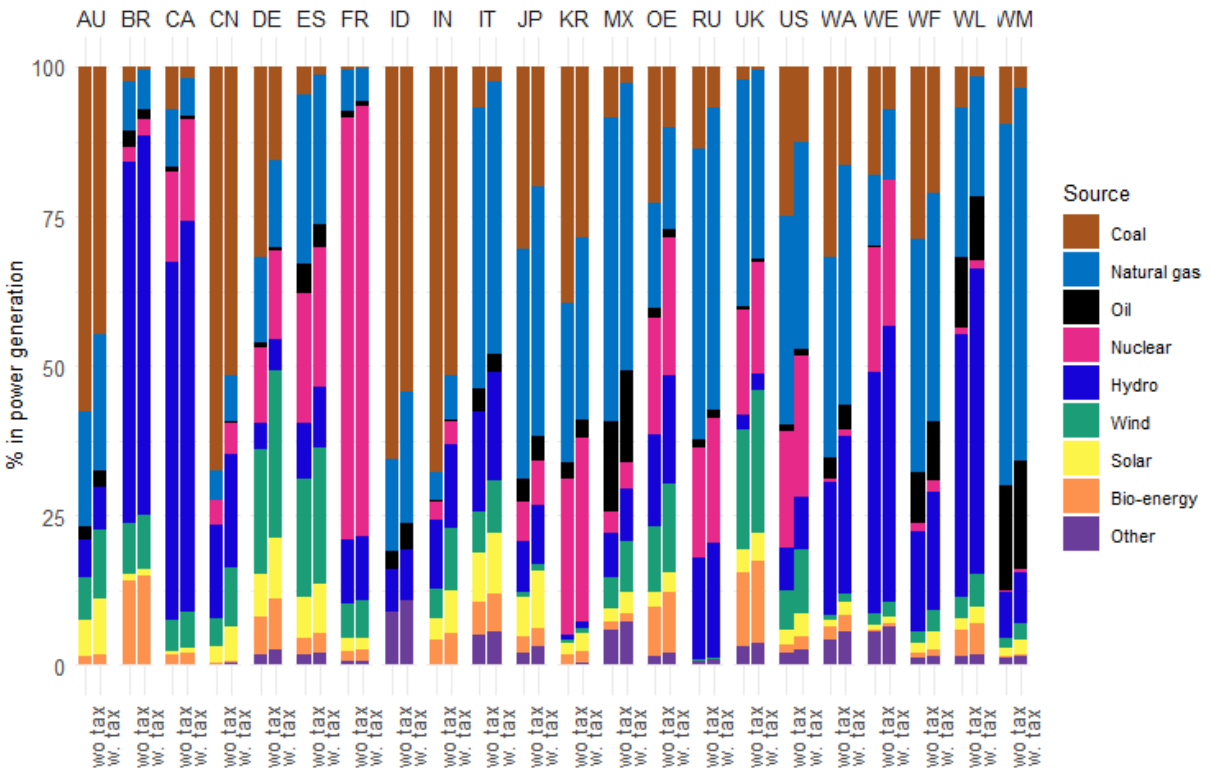


Figure 17. Power generation changes without and with a carbon tax of 100€/tCO_2 in 2030 in all countries

4.2 Test the model as a whole

For the validation part, we performed benchmark simulations to evaluate the results of the whole model, under a set of pre-defined scenario protocols and indicators, drawing from the diagnostic runs established by Kriegler et al. (2015)—see Table 10.

Table 11. Illustrative diagnostic scenario adapted from Kriegler et al. (2015)

Base	No policy baseline
C30-const	For t < 2025: Fix to Base For t in [2025, 2050]: Tax(t) = 30 USD
C80-const	For t < 2025: Fix to Base For t in [2025, 2050]: Tax(t) = 80 USD
C30-gr5	For t < 2025: Fix to Base For t in [2025, 2050]: Tax(t) = 30 USD * $1.05^{(t-2035)}$ (USD 30 reached in 2035)
C80-gr5	For t < 2025: Fix to Base For t in [2025, 2050]: Tax(t) = 80 USD * $1.05^{(t-2035)}$ (USD 80 reached in 2035)

Across all four benchmark scenarios and in every region, CO_2 emissions from fossil fuels decline following the introduction of carbon pricing (Figure 18). The largest reduction in 2050 occurs in the "C80-gr5" scenario, where the carbon price reaches 166US$/t$CO_2$ (around 150€). For example, in China—the highest-emitting region—total CO_2 emissions in the C30-const scenario fall from 9.3 Gt to 7.5 Gt by 2030, while in the C80-const scenario they are further reduced to 5.9 Gt. Similar emission levels are reached in 2030 under the C30-gr5 and C80-gr5 scenarios, since the carbon price is identical at that time; however, emissions continue to decline thereafter, reaching 6.3 Gt and 3.8 Gt respectively by 2050. At the sectoral level, Chinese CO_2 emissions decline across all sectors. In the "C80-gr5" scenario, the steepest reductions occur in the power generation sector—from 4.5 Gt in 2020 to 1 Gt in 2050—and in industry, where emissions fall from

Funded by
the European Union

3.9 Gt to 2.2 Gt over the same period.

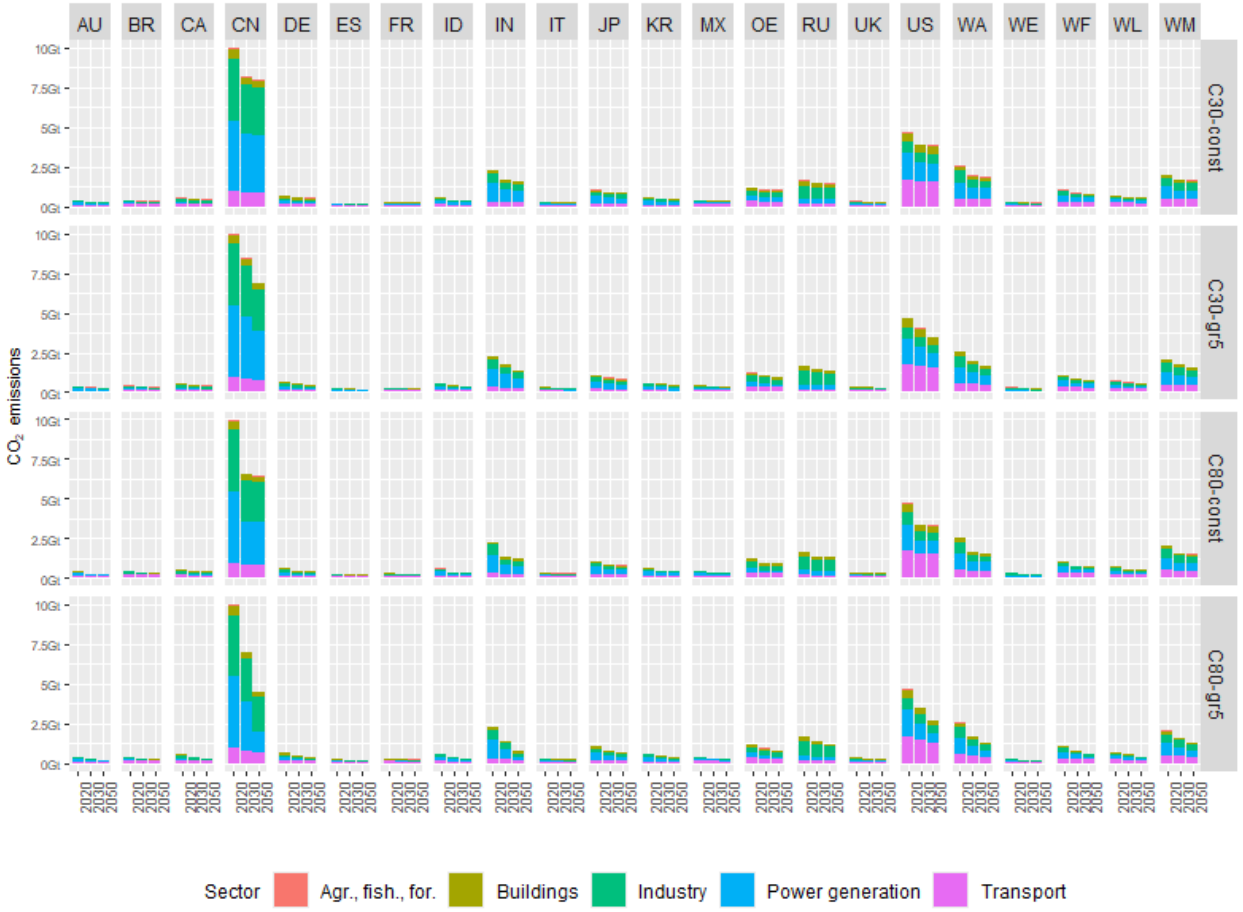


Figure 18. CO_2 emissions from fossil fuels combustion in the benchmark scenarios

In the power generation sector, CO_2 emissions sharply decline across all regions. For example, in India, emissions fall from 1.1 Gt in 2020 to about 0.8 Gt in 2030 under the C30-const scenario, and to 0.2 Gt in 2050 under the C80-gr5 scenario. To achieve such substantial reductions worldwide, the power generation mix shifts away from fossil fuels—especially coal (Figure 19). In India, in the C80-gr5 scenario, coal accounts for 64% of power generation in 2020, dropping to 39% in 2030 and only 7% in 2050. Coal is replaced by several non-emitting technologies, including hydropower (increasing from 11% in 2020 to 23% in 2050), nuclear (9% to 20%), wind (5% to 11%), and solar (3% to 14%).

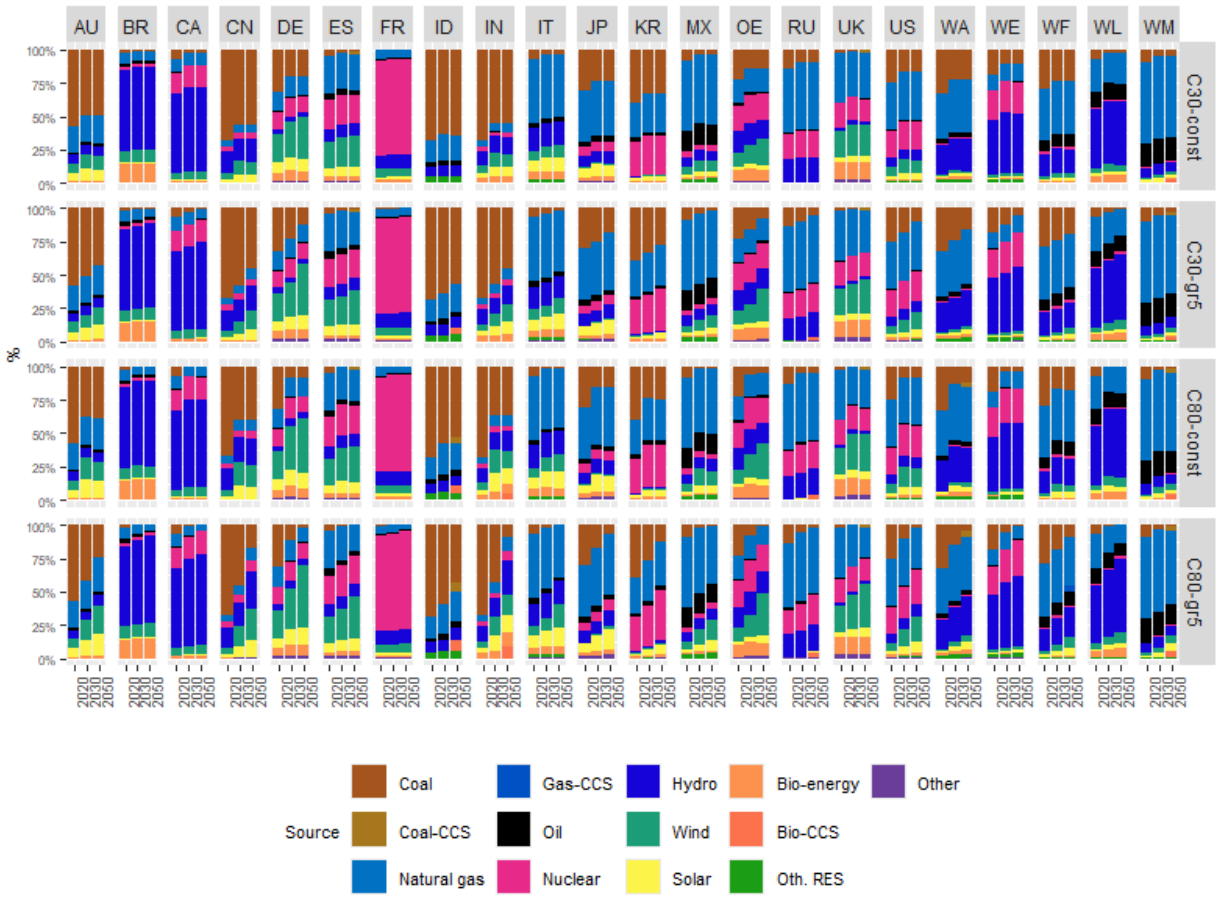


Figure 19. Power generation mix in the benchmark scenarios in all countries

Final energy consumption is also declining, although at a slower rate than CO_2 emissions (Figure 20). For example, in the United States, final energy consumption is about 67EJ in 2020, including 29EJ in transport, 21EJ in buildings, 16EJ in industry, and 1EJ in agriculture, fisheries, and forestry (AFOFI). In the "C30-const" scenario, final energy use is projected to reach 6 EJ by 2030, with 27EJ in transport, 20EJ in buildings, 1 EJ in industry, and 0.7EJ in AFOFI. The decline is more pronounced in the "C80-gr5" scenario, with total consumption falling to 58EJ in 2030 and 50EJ in 2050, including 23EJ in transport, 17EJ in buildings, 9EJ in industry, and 0.5EJ in AFOFI.

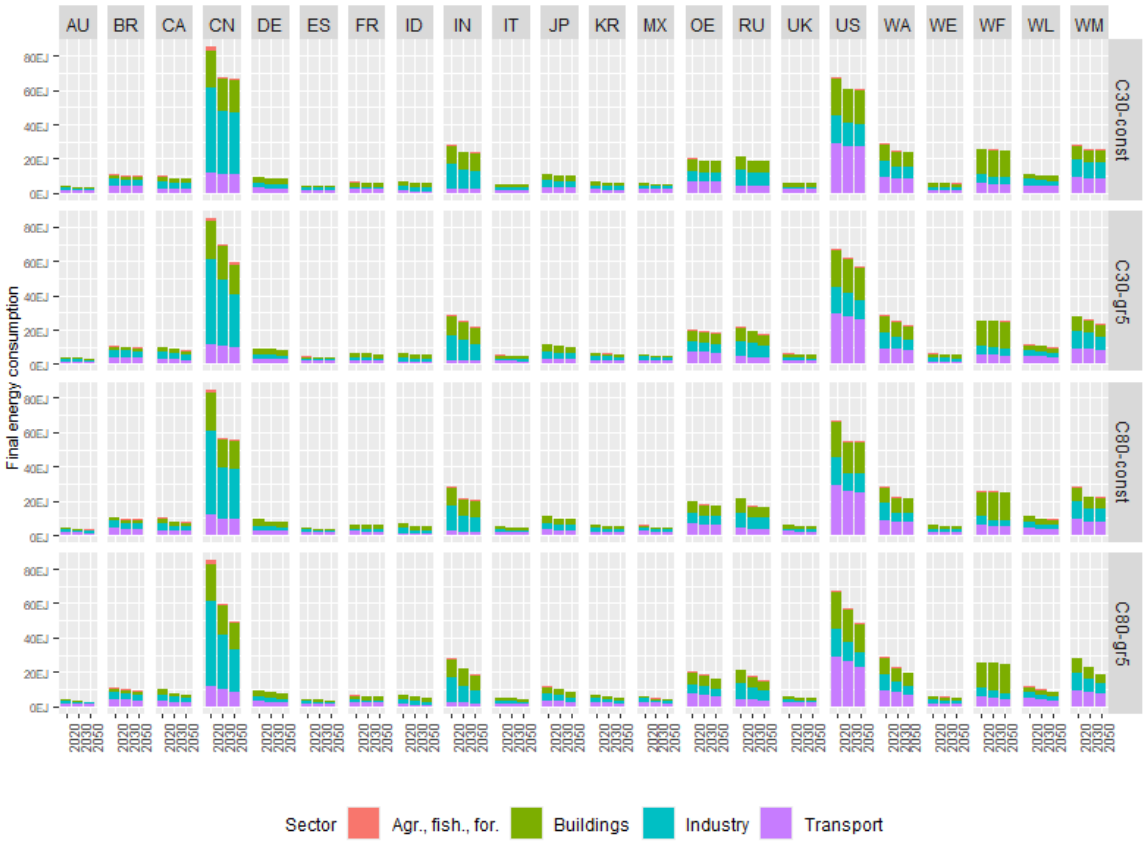


Figure 20. Final energy consumption by sector in the benchmark scenarios in all countries

In terms of fuels, coal use is declining across all regions (Figure 21). Globally, coal consumption for final use was 42.7EJ in 2020 and is projected to fall to 22.6EJ in 2030 under the "C30-const" scenario, and to 15.5EJ in 2030 and 7.6EJ in 2050 under the "C80-gr5" scenario. Gas consumption also decreases significantly in this scenario, dropping from 73.3EJ in 2020 to 50.3EJ in 2030 and 34.7EJ in 2050. Final oil consumption follows a similar downward trend, but at a slower rate, declining from 150EJ in 2020 to 132EJ in 2030 and 110EJ in 2050, representing a substantial absolute reduction. Electricity consumption shows a slight decline, from 88.6EJ in 2020 to 75.7EJ in 2050 in the "C80-gr5" scenario, while bioenergy use moderately increases, from 41.8EJ in 2020 to 46.3EJ in 2030 and 48.5EJ in 2050.

Funded by
the European Union

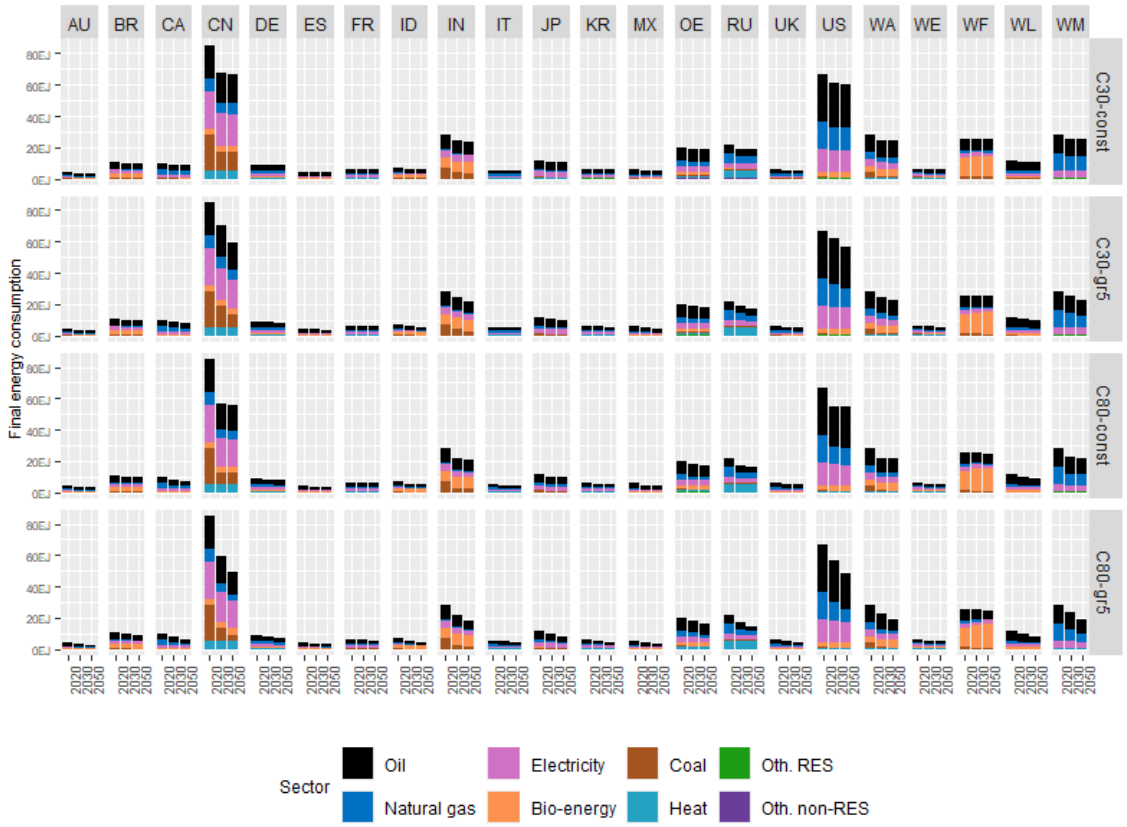


Figure 21. Final energy consumption by fuel in the benchmark scenarios in all countries

The implementation of carbon pricing has a negative impact on global GDP, which declines by 1.6% in 2030 and by 2% in both 2040 and 2050 under the "C30-const" scenario. Under the "C80-gr5" scenario, the GDP loss is more pronounced, reaching 2.7% in 2030, 4.3% in 2040, and up to 6% in 2050 (Figure 22). These GDP losses are mainly the result of rising energy costs, which increase production expenses globally and, in turn, slow down economic activity, acting as a negative productivity shock. It is important to note that, in the benchmark scenarios, carbon revenues are not recycled, which explains the magnitude of these GDP declines. The main contributor to the global GDP reduction in 2050 under the "C80-gr5" scenario is China, accounting for 1.7 percentage points (ppt) of the total 6-ppt decline, followed by India with 1.9 ppt, and both the rest of Asia (WA) and the United States with 0.6 ppt each.

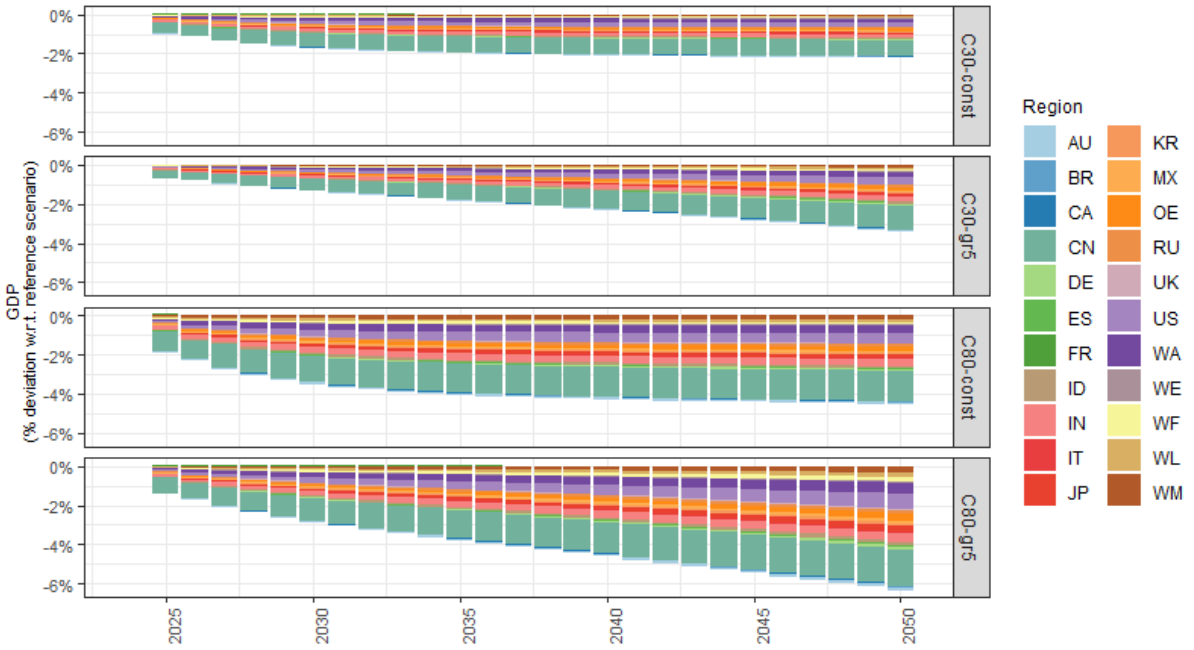


Figure 22. Contribution of regional GDP to global GDP deviation in the benchmark scenarios
Note: In the four benchmark scenarios, the carbon prices are implemented without recycling of the carbon revenues.

The introduction of a carbon price pathway into the model produces coherent results. Global CO_2 emissions decline sharply, although the pace of reduction varies across regions. Decarbonization occurs first in the power generation sector, both in relative and absolute terms, primarily through a decline in coal use and an uptake of wind and solar. This is followed by reductions in the industry and buildings sectors, while the transport sector experiences a more gradual decarbonization. The model also indicates that emissions reductions are driven both by a decrease in total energy demand and by fuel substitution. Finally, implementing decarbonization through carbon pricing without any recycling mechanisms imposes economic costs, leading to GDP losses—particularly in developing or less advanced economies, where carbon prices represent relatively larger economic shocks. These findings are consistent with the general patterns observed in global and regional decarbonization pathways (e.g. Bistline, 2021; Boitier et al., 2023).

5 Model Manual

5.1 Software

Table 12 summarises the required software to run the different step of the model. Before the simulations, the model requires Windows OS (Windows 11 recommended), with a minimum 8 Gb of RAM (recommended) and 20Gb storage (recommended).

Table 12. Software requirements

Data collecting	Data processing	Model simulation
Python 3.12.10 including the following package: pymrio v0.5.4 Jupyter Notebook	Python 3.12.10 including the following packages: pymrio 0.5.4[7], Pandas 2.2.3, Numpy 2.2.6; Iode 1.0.4[8]) Jupyter Notebook	Python 3.12.10 including the following packages: pymrio 0.5.4, Pandas 2.2.3, Numpy 2.2.6; Iode 1.0.4 Iode GUI v1.0.4 Jupyter Notebook Microsoft Excel or equivalent Workbook

5.2 Model and baseline generation

Figure 22 presents the general framework used to generate the model and simulate a baseline (or reference) scenario.

Once the required software is properly installed, the process begins with the collection and processing of the EXIOBASE database[9]. This step gathers and processes a large share of the necessary economic variables for the reference year—here, 2019. In addition, pre-processed files are used to calculate gross fixed capital formation by region and sector, as well as the flow of income for households and governments by region, ensuring consistency with the information available in EXIOBASE. Subsequently, data on energy quantities and prices are loaded, processed and used to complete the calculation of certain economic variables. Similarly, GHG emissions are loaded and allocated to economic activities and households in proportion to their fossil energy consumption or, for industrial process emissions, according to their production levels. A set of remaining variables (e.g., unemployment, population, interest rates) are then gathered and used to complete and finalise the database of the model. A current version of the database is already uploaded in the models' GitHub page; however, this stage is necessary for users intending to make changes and adaptations to the underlying data and assumptions.

When the core database is created, the next step is the creation of the equations, which is done block by block, as well as the calculation of necessary variables from the core database. The equations can be separated by blocks: the economic model that includes the supply/production side, households'

[7] https://pymrio.readthedocs.io/en/latest/intro.html
[8] https://iode.readthedocs.io/en/latest/
[9] We note that the current version of the model uses EXIOBASE v3.8.2, we recommend to manually download to ensure that the appropriate version is used. Otherwise, the pymrio package may by default download the latest available version, which is not aligned with NEMESIS-World.

consumption, international trade, income flows for households and governments, and the labour market. Concerning the energy and climate module, equations are grouped in two main blocks: i) energy quantities in physical and monetary units and prices; and ii) the GHG emissions block. As a final step, a set of parameters is loaded—i.e., those related to behavioural equations—while others are directly calculated based on raw data to finalise the model generation.

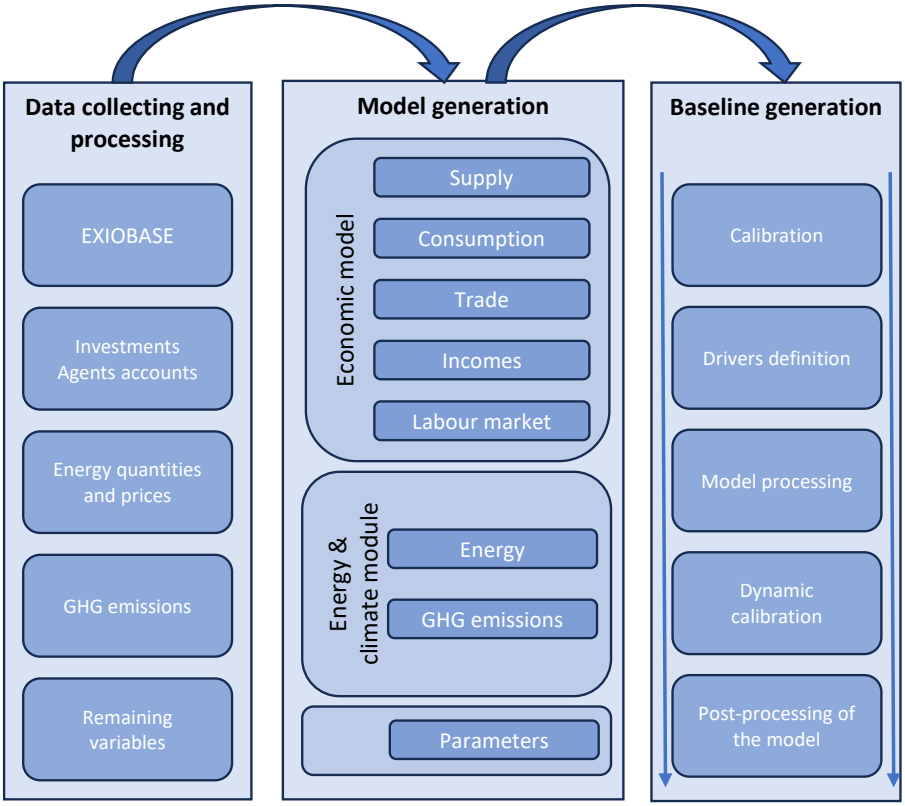


Figure 22. Scheme of the model and baseline generation

The next step consists of generating the baseline scenario. First, all variables are extrapolated over the simulation period, assuming that values remain constant, while some key equations are inversed to allow calibration over time. Thus, this calibration process ensures the stability of the model and allows performing tests capturing the main properties and behaviour of the model.

Running a baseline (or reference) scenario is based on a set of predefined options. At minimum, this requires quantifying the exogenous variables, as defined for the reference scenario: population (by age and qualification level), interest rates, and fossil fuel prices. Usually, a baseline for the economic development path is also defined—including GDP growth, inflation, and the long-term unemployment rate—which are typically endogenous outputs of the model. To align model outputs with this predefined economic path, calibration parameters in key equations are adjusted (shocked). The choice of which equations to adjust depends on both the outputs that need to match projections and the requirement to maintain the model's internal consistency. For example, targeted GDP growth is achieved through its components: household private consumption, government final consumption, gross fixed capital formation, imports, and exports. Specifically, for gross fixed capital formation, the calibration parameters of investment demand in each sector are iteratively adjusted to align with the total economy's investment target, which, in the long run, must converge to a fixed share of GDP. Similar adjustments are made for private consumption, while ensuring consistency between wages and income. This last step, , will start with the scenarios framework definition of DIAMOND (WP5) to set up a policy-based baseline generation in the beginning of the last year of the project.

References

Antoszewski, Michał. 2019. « Wide-Range Estimation of Various Substitution Elasticities for CES Production Functions at the Sectoral Level ». *Energy Economics* 83 (septembre): 272-89. https://doi.org/10.1016/j.eneco.2019.07.016.

Armington, Paul S. 1969. « A Theory of Demand for Products Distinguished by Place of Production ». *Staff Papers - International Monetary Fund* 16 (1): 159-78. https://doi.org/10.2307/3866403.

Baccianti, Claudio. 2013. « Estimation of Sectoral Elasticities of Substitution Along the International Technology Frontier ». *SSRN Electronic Journal*, publication en ligne anticipée. https://doi.org/10.2139/ssrn.2353824.

Bajzik, Josef, Tomas Havranek, Zuzana Irsova, et Jiri Schwarz. 2020. « Estimating the Armington Elasticity: The Importance of Study Design and Publication Bias ». *Journal of International Economics* 127 (novembre): 103383. https://doi.org/10.1016/j.jinteco.2020.103383.

Bistline, John E.T. 2021. « Roadmaps to Net-Zero Emissions Systems: Emerging Insights and Modeling Challenges ». *Joule* 5 (10): 2551-63. https://doi.org/10.1016/j.joule.2021.09.012.

Bjelle, Eivind Lekve, Johannes Többen, Konstantin Stadler, et al. 2020. « Adding Country Resolution to EXIOBASE: Impacts on Land Use Embodied in Trade ». *Journal of Economic Structures* 9 (1): 14. https://doi.org/10.1186/s40008-020-0182-y.

Boitier, Baptiste, Pierre Le Mouël, Julien Ravet, et Paul Zagamé. 2022. « The NEMESIS Macro-Econometric Model ». In *Macroeconomic Modelling of R&D and Innovation Policies*, édité par Ufuk Akcigit, Cristiana Benedetti Fasil, Giammario Impullitti, Omar Licandro, et Miguel Sanchez-Martinez. International Economic Association Series. Springer International Publishing. https://doi.org/10.1007/978-3-030-71457-4_7.

Boitier, Baptiste, Alexandros Nikas, Ajay Gambhir, et al. 2023. « A Multi-Model Analysis of the EU's Path to Net Zero ». *Joule* 7 (12): 2760-82. https://doi.org/10.1016/j.joule.2023.11.002.

Brécard, Dorothée, Arnaud Fougeyrollas, Pierre Le Mouël, Lionel Lemiale, et Paul Zagamé. 2006. « Macro-Economic Consequences of European Research Policy: Prospects of the Nemesis Model in the Year 2030 ». *Research Policy* 35 (7): 910-24. https://doi.org/10.1016/j.respol.2006.03.001.

Cao, Jing, Mun S. Ho, et Rong Ma. 2020. « Analyzing Carbon Pricing Policies Using a General Equilibrium Model with Production Parameters Estimated Using Firm Data ». *Energy Economics* 92 (octobre): 104958. https://doi.org/10.1016/j.eneco.2020.104958.

Crippa, M., Guizzardi, D., Pagani, F., et al. 2024. « GHG Emissions of All World Countries. » European Commossion Publications Office. https://data.europa.eu/doi/10.2760/4002897.

Dissou, Yazid, Lilia Karnizova, et Qian Sun. 2015. « Industry-Level Econometric Estimates of Energy-Capital-Labor Substitution with a Nested CES Production Function ». *Atlantic Economic Journal* 43 (1): 107-21. https://doi.org/10.1007/s11293-014-9443-1.

Donnelly, William, Johnson, Kyle, et Tsigas, Marinos. 2004. « Revised Armington Elasticities of Substitution for the USITC Model and the Concordance for Constructing a Consistent Set for the GTAP Model ». Office of Economics Research note - US Information Trade Commission, janvier 1. https://www.usitc.gov/publications/332/ec200401a.pdf.

Engle, Robert F., et C. W. J. Granger. 1987. « Co-Integration and Error Correction: Representation, Estimation, and Testing ». *Econometrica* 55 (2): 251. https://doi.org/10.2307/1913236.

Eurostat. 2021. « FIGARO methodology ». mai 1. https://ec.europa.eu/eurostat/documents/51957/12767369/Figaro-methodology.pdf/487255c9-903a-0cb7-f5e2-73f37e35f196?t=1620750704022.

Huo, Jingwen, Peipei Chen, Klaus Hubacek, Heran Zheng, Jing Meng, et Dabo Guan. 2022. « Full-scale, near Real-time Multi-regional Input–Output Table for the Global Emerging Economies (EMERGING) ». *Journal of Industrial Ecology* 26 (4): 1218-32. https://doi.org/10.1111/jiec.13264.

IEA. 2025. « Energy Prices ». IEA_2025_EnrPrices. mars 1. https://www.iea.org/data-and-statistics/data-product/energy-prices.

International Monetary Fund. 2025. *World Economic Outlook, April 2025: A Critical Juncture amid Policy Shifts*. International Monetary Fund.

KC, Samir, Dhakad Moradhvaj, Michaela Potancokova, et al. 2024. « Wittgenstein Center (WIC) Population and Human Capital Projections - 2023 ». Version V14. Zenodo, février 7. https://doi.org/10.5281/ZENODO.14718294.

Kemfert, Claudia. 1998. « Estimated Substitution Elasticities of a Nested CES Production Function Approach for Germany ». *Energy Economics* 20 (3): 249-64. https://doi.org/10.1016/s0140-9883(97)00014-5.

Koesler, Simon, et Michael Schymura. 2015. « Substitution Elasticities in a Constant Elasticity of Substitution Framework – Empirical Estimates Using Nonlinear Least Squares ». *Economic Systems Research* 27 (1): 101-21. https://doi.org/10.1080/09535314.2014.926266.

Kriegler, Elmar, Nils Petermann, Volker Krey, et al. 2015. « Diagnostic Indicators for Integrated Assessment Models of Climate Policy ». *Technological Forecasting and Social Change* 90 (janvier): 45-61. https://doi.org/10.1016/j.techfore.2013.09.020.

Krugman, Paul. 1991. « Increasing Returns and Economic Geography ». *Journal of Political Economy* 99 (3): 483-99. https://doi.org/10.1086/261763.

Lenzen, Manfred, Arne Geschke, James West, et al. 2021. « Implementing the Material Footprint to Measure Progress towards Sustainable Development Goals 8 and 12 ». *Nature Sustainability* 5 (2): 157-66. https://doi.org/10.1038/s41893-021-00811-6.

Lenzen, Manfred, Daniel Moran, Keiichiro Kanemoto, et Arne Geschke. 2013. « BUILDING EORA: A GLOBAL MULTI-REGION INPUT–OUTPUT DATABASE AT HIGH COUNTRY AND SECTOR RESOLUTION ». *Economic Systems Research* 25 (1): 20-49. https://doi.org/10.1080/09535314.2013.769938.

Mantzos, Leonidas, Thomas Wiesenthal, Frederik Neuwahl, et Máté Rozsai,. 2019. *The POTEnCIA Central Scenario: An EU Energy Outlook to 2050*. Publications Office. https://data.europa.eu/doi/10.2760/32835.

Nikas, Alexandros, Haris Doukas, et Andreas Papandreou. 2019. « A Detailed Overview and Consistent Classification of Climate-Economy Models ». In *Understanding Risks and Uncertainties in Energy and Climate Policy*, édité par Haris Doukas, Alexandros Flamos, et Jenny Lieu. Springer International Publishing. https://doi.org/10.1007/978-3-030-03152-7_1.

OECD. 2019. *Taxing Energy Use 2019: Using Taxes for Climate Action*. Taxing Energy Use. OECD. https://doi.org/10.1787/058ca239-en.

OECD. 2024a. « Annual capital formation by economic activity ». Version 2024. octobre 1. https://data-explorer.oecd.org.

OECD. 2024b. « Annual non-financial accounts by institutional sector (Expenditure/Revenue) ». Version 2024. octobre 1. https://data-explorer.oecd.org.

OECD. 2024c. « Inter-Country Input-Output tables ». Version 2024. avril 1. https://www.oecd.org/en/data/datasets/inter-country-input-output-tables.html.

OECD. 2024d. « National Accounts at a Glance ». OECD, octobre 1. https://doi.org/10.1787/22200444.

OECD. 2025. « Key short-term economic indicators ». juin 1. https://data-explorer.oecd.org.

Okagawa, Azusa et Ban, Kanemi. 2028. « Estimation of substitution elasticities for CGE models ». *Discussion Papers in Economics and Business*, Osaka University, Graduate School of Economics and Osaka School of International Public Policy (OSIPP), n°s 08-16 (janvier). https://www.researchgate.net/publication/5206877_Estimation_of_Substitution_Elasticities_for_CGE_Models.

Stadler, Konstantin, Richard Wood, Tatyana Bulavskaya, et al. 2021. « EXIOBASE 3 ». Version 3.8.2. Zenodo, octobre 21. https://doi.org/10.5281/ZENODO.5589597.

UNData. 2025a. « Energy Balance DataFlow (DF_UNData_EnergyBalance) ». mars 1. https://unstats.un.org/unsd/energystats/.

UNData. 2025b. « Energy Statistics (DF_UNDATA_ENERGY) ». mars 1. https://unstats.un.org/unsd/energystats/.

Van Der Werf, Edwin. 2007. « Production Functions for Climate Policy Modeling: An Empirical Analysis ». *SSRN Electronic Journal*, publication en ligne anticipée. https://doi.org/10.2139/ssrn.983034.

Appendix

Table 13. NEMESIS World regions' mapping with EXIOBASE

NEMESIS World		EXIOBASE v3.8.2	
AU	Australia	AU	Australia
BR	Brazil	BR	Brazil
CA	Canada	CA	Canada
CN	China	CN	China
DE	Germany	DE	Germany
ES	Spain	ES	Spain
FR	France	FR	France
ID	Indonesia	ID	Indonesia
IN	India	IN	India
IT	Italy	IT	Italy
JP	Japan	JP	Japan
KR	South Korea	KR	South Korea
MX	Mexico	MX	Mexico
OE	Other European Union	AT	Austria
		BE	Belgium
		BG	Bulgaria
		CY	Cyprus
		CZ	Czechia
		DK	Denmark
		EE	Estonia
		FI	Finland
		GR	Greece
		HR	Croatia
		HU	Hungary
		IE	Ireland
		LT	Lithuania
		LU	Luxembourg
		LV	Latvia
		MT	Malta
		NL	Netherlands
		PL	Poland
		PT	Portugal
		RO	Romania
		SE	Sweden
		SI	Slovenia
		SK	Slovakia
RU	Russia	RU	Russia
UK	United-Kingdom	GB	United-Kingdom
US	United States of America	US	United States of America
WA	RoW Asia and Pacific	TR	Turkey
		TW	Taiwan
		WA	RoW Asia and Pacific
WE	RoW Europe	CH	Switzerland
		NO	Norway
		WE	RoW Europe
WF	RoW Africa	WF	RoW Africa
WF	RoW Africa	ZA	South Africa
WL	RoW America	WL	RoW America
WM	RoW Middle East	WM	RoW Middle East

Table 14. NEMESIS World sectors' mapping with EXIOBASE

NEMESIS World		EXIOBASE v3.8.2	
01	Agriculture - vegetable	001	Cultivation of paddy rice
		002	Cultivation of wheat
		003	Cultivation of cereal grains nec
		004	Cultivation of vegetables, fruit, nuts
		005	Cultivation of oil seeds
		006	Cultivation of sugar cane, sugar beet
		007	Cultivation of plant-based fibers
		008	Cultivation of crops nec
02	Agriculture - animals	009	Cattle farming
		010	Pigs farming
		011	Poultry farming
		012	Meat animals nec
		013	Animal products nec
		014	Raw milk
		015	Wool, silk-worm cocoons
		016	Manure treatment (conventional), storage and land application
		017	Manure treatment (biogas), storage and land application
03	Forestry	018	Forestry, logging and related service activities (02)
04	Fishery	019	Fishing, operating of fish hatcheries and fish farms; service activities incidental to fishing (05)
05	Mining of coal	020	Mining of coal and lignite; extraction of peat (10)
06	Extraction of oil	021	Extraction of crude petroleum and services related to crude oil extraction, excluding surveying
		023	Extraction, liquefaction, and regasification of other petroleum and gaseous materials
07	Extraction of natural gas	022	Extraction of natural gas and services related to natural gas extraction, excluding surveying
08	Other mining	024	Mining of uranium and thorium ores (12)
		025	Mining of iron ores
		026	Mining of copper ores and concentrates
		027	Mining of nickel ores and concentrates
		028	Mining of aluminium ores and concentrates
		029	Mining of precious metal ores and concentrates
		030	Mining of lead, zinc and tin ores and concentrates
		031	Mining of other non-ferrous metal ores and concentrates
		032	Quarrying of stone
		033	Quarrying of sand and clay
		034	Mining of chemical and fertilizer minerals, production of salt, other mining and quarrying n.e.c.
09	Manufacture of food, beverage and tobacco	035	Processing of meat cattle
		036	Processing of meat pigs

Funded by the European Union

		037	Processing of meat poultry
		038	Production of meat products nec
		039	Processing vegetable oils and fats
		040	Processing of dairy products
		041	Processed rice
		042	Sugar refining
		043	Processing of Food products nec
		044	Manufacture of beverages
		045	Manufacture of fish products
		046	Manufacture of tobacco products (16)
10	Manufacture of textiles, wearing apparel and leather products	047	Manufacture of textiles (17)
		048	Manufacture of wearing apparel; dressing and dyeing of fur (18)
		049	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear (19)
11	Manufacture of wood and wood products	050	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials (20)
		051	Re-processing of secondary wood material into new wood material
12	Manufacture of pulp, paper and printing products	052	Pulp
		053	Re-processing of secondary paper into new pulp
		054	Paper
		055	Publishing, printing and reproduction of recorded media (22)
13	Manufacture of coke	056	Manufacture of coke oven products
14	Manufacture of petroleum and nuclear products	057	Petroleum Refinery
		058	Processing of nuclear fuel
15	Chemicals - platics	059	Plastics, basic
		060	Re-processing of secondary plastic into new plastic
16	Chemicals - fertilisers	061	N-fertiliser
		062	P- and other fertiliser
17	Cheminals - others	063	Chemicals nec
18	Manufacture of rubber and plactic products	064	Manufacture of rubber and plastic products (25)
19	Manufacture of glass	065	Manufacture of glass and glass products
		066	Re-processing of secondary glass into new glass
20	Manufacture of cement and lime	069	Manufacture of cement, lime and plaster
		070	Re-processing of ash into clinker
21	Manufacture of other non-metallic mineral products	067	Manufacture of ceramic goods
		068	Manufacture of bricks, tiles and construction products, in baked clay
		071	Manufacture of other non-metallic mineral products n.e.c.
22	Manufacture of iron and steel	072	Manufacture of basic iron and steel and of ferro-alloys and first products thereof
		073	Re-processing of secondary steel into new steel

23	Manufacture of other basic metals	074	Precious metals production
		075	Re-processing of secondary preciuos metals into new preciuos metals
		078	Lead, zinc and tin production
		079	Re-processing of secondary lead into new lead, zinc and tin
		080	Copper production
		081	Re-processing of secondary copper into new copper
		082	Other non-ferrous metal production
		083	Re-processing of secondary other non-ferrous metals into new other non-ferrous metals
		084	Casting of metals
24	Aluminium production	076	Aluminium production
		077	Re-processing of secondary aluminium into new aluminium
25	Manufacture of fabricated metal products	085	Manufacture of fabricated metal products, except machinery and equipment (28)
26	Manufacture of machinery and equipment	086	Manufacture of machinery and equipment n.e.c. (29)
27	Manufacture of office machinery and computers	087	Manufacture of office machinery and computers (30)
28	Manufacture of electrical machinery and apparatus	088	Manufacture of electrical machinery and apparatus n.e.c. (31)
29	Manufacture of radio, television and communication equipment and apparatus	089	Manufacture of radio, television and communication equipment and apparatus (32)
30	Manufacture of medical, precision and optical instruments, watches and clocks	090	Manufacture of medical, precision and optical instruments, watches and clocks (33)
31	Manufacture of motor vehicles, trailers and semi-trailers	091	Manufacture of motor vehicles, trailers and semi-trailers (34)
32	Manufacture of other transport equipment	092	Manufacture of other transport equipment (35)
33	Other manufacturing	093	Manufacture of furniture; manufacturing n.e.c. (36)
34	Wastes treatment and recycling	094	Recycling of waste and scrap
		095	Recycling of bottles by direct reuse
		139	Incineration of waste: Food
		140	Incineration of waste: Paper
		141	Incineration of waste: Plastic
		142	Incineration of waste: Metals and Inert materials
		143	Incineration of waste: Textiles
		144	Incineration of waste: Wood
		145	Incineration of waste: Oil/Hazardous waste
		149	Composting of food waste, incl. land application
		150	Composting of paper and wood, incl. land application
		151	Waste water treatment, food
		152	Waste water treatment, other

Funded by
the European Union

		153	Landfill of waste: Food
		154	Landfill of waste: Paper
		155	Landfill of waste: Plastic
		156	Landfill of waste: Inert/metal/hazardous
		157	Landfill of waste: Textiles
		158	Landfill of waste: Wood
35	Production of electricity	096	Production of electricity by coal
		097	Production of electricity by gas
		098	Production of electricity by nuclear
		099	Production of electricity by hydro
		100	Production of electricity by wind
		101	Production of electricity by petroleum and other oil derivatives
		102	Production of electricity by biomass and waste
		103	Production of electricity by solar photovoltaic
		104	Production of electricity by solar thermal
		105	Production of electricity by tide, wave, ocean
		106	Production of electricity by Geothermal
		107	Production of electricity nec
36	Transmission of electricity	108	Transmission of electricity
37	Distribution and trade of electricity	109	Distribution and trade of electricity
38	Manufacture of gas; distribution of gaseous fuels through mains	110	Manufacture of gas; distribution of gaseous fuels through mains
		146	Biogasification of food waste, incl. land application
		147	Biogasification of paper, incl. land application
		148	Biogasification of sewage slugde, incl. land application
39	Steam and hot water supply	111	Steam and hot water supply
40	Water distribution	112	Collection, purification and distribution of water (41)
41	Construction	113	Construction (45)
		114	Re-processing of secondary construction material into aggregates
42	Trade	115	Sale, maintenance, repair of motor vehicles, motor vehicles parts, motorcycles, motor cycles parts and accessoiries
		116	Retail sale of automotive fuel
		117	Wholesale trade and commission trade, except of motor vehicles and motorcycles (51)
		118	Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods (52)
43	Hotels and restaurants	119	Hotels and restaurants (55)
44	Transport via railways	120	Transport via railways
45	Other land transport	121	Other land transport
46	Sea and coastal water transport	123	Sea and coastal water transport
47	Inland water transport	124	Inland water transport
48	Air transport	125	Air transport (62)
49	Other transport	122	Transport via pipelines

		126	Supporting and auxiliary transport activities; activities of travel agencies (63)
		127	Post and telecommunications (64)
50	Finance	128	Financial intermediation, except insurance and pension funding (65)
		130	Activities auxiliary to financial intermediation (67)
51	Insurance	129	Insurance and pension funding, except compulsory social security (66)
52	Real estate activities	131	Real estate activities (70)
53	Information and communication	133	Computer and related activities (72)
54	Research and development	134	Research and development (73)
55	Other business activities	132	Renting of machinery and equipment without operator and of personal and household goods (71)
		135	Other business activities (74)
56	Public administration and defence; compulsory social security	136	Public administration and defence; compulsory social security (75)
57	Education	137	Education (80)
58	Health and social work	138	Health and social work (85)
59	Other services activities	159	Activities of membership organisation n.e.c. (91)
		160	Recreational, cultural and sporting activities (92)
		161	Other service activities (93)
		162	Private households with employed persons (95)
		163	Extra-territorial organizations and bodies

Funded by
the European Union

Table 15. Mapping of Households' consumption categories with economic activities

		Necessities					Transportation										Rest							Trade
		Essentials		Housing			ICE		PHEV		BEV		Oth. Inland Tr.		Air Transp.	Water Transp.	Oth. Transp.	Non-market serv.			Rest				
		Food	Cloth.	Rent	Water & Waste	Heat & Colling	Vehicle	Fuel	Vehicle.	Fuel	Vehicle	Fuel	Train	Other				Education	Health	Other	Hotels & Res.	LEIS ICT	LEIS Other	Equipment	Rest	
01	Agriculture - vegetable	x																							
02	Agriculture - animals	x																							
03	Forestry					x																		x		
04	Fishery	x																								
05	Mining of coal					x																				
06	Extraction of oil					x																				
07	Extraction of natural gas					x																				
08	Other mining																								x	
09	Manufacture of food, [...]	x																								
10	Manufacture of textiles [...]		x																							
11	Manufacture of wood [...]																							x		
12	Manufacture of pulp, paper [...]																						x			
13	Manufacture of coke					x																				
14	Manufacture of petroleum [...]					x		x		x																
15	Chemicals - platics																							x		
16	Chemicals - fertilisers																							x		
17	Cheminals - others																							x		
18	Manufacture of rubber [...]																							x		
19	Manufacture of glass																							x		
20	Manufacture of cement [...]																							x		
21	Manufacture of other nmm																							x		
22	Manufacture of iron and steel																							x		
23	Manuf. of other basic metals																							x		
24	Aluminium production																							x		
25	Manuf. of fabricated metal [...]																							x		
26	Manufacture of machinery [...]																							x		
27	Manuf. of office machinery [...]																							x		
28	Manuf.of elec. machinery [...]																							x		

29	Manufacture of radio, [...]s																				x		
30	Manufacture of medical, [...]																				x		
31	Manuf. of motor vehicles, [...]						x		x		x												
32	Manuf. of other transp. equip.						x		x		x												
33	Other manufacturing																				x		
34	Wastes treatment and recycling				x																		
35	Production of electricity					x			x		x												
36	Transmission of electricity					x			x		x												
37	Distribution and trade of elec.					x			x		x												
38	Manufacture of gas; [...]					x		x	x														
39	Steam and hot water supply					x																	
40	Water distribution				x																		
41	Construction																				x		
42	Trade																						x
43	Hotels and restaurants																			x			
44	Transport via railways											x											
45	Other land transport												x										
46	Sea and coastal water transport														x								
47	Inland water transport														x								
48	Air transport													x									
49	Other transport															x							
50	Finance																					x	
51	Insurance																					x	
52	Real estate activities			x																			
53	Inform. and communication																			x			
54	Research and development																					x	
55	Other business activities																					x	
56	Public admin. and defence; [...]																		x				
57	Education																	x					
58	Health and social work																x						
59	Other services activities																		x				

Funded by
the European Union