ENhancing our understanding of Trade Impacts on Climate, industries, and the Environment

Funded by the European Union

Project funded by

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Education, Research and Innovation SERI

D4.1- Reference Scenario and Metrics

WP4 – Explore the effects of trade on climate and environment

27/02/2026

Disclaimer

Copyright Message

Grant Agreement Number	101184775	**Acronym**	ENTICE
Full Title	ENhanced understanding of Trade Impacts on Climate, industries, and the Environment		
Topic	HORIZON-CL5-2024-D1-01-04		
Funding scheme	HORIZON Research and Innovation Actions		
Start Date	January 2025	**Duration**	48 Months
Project URL	http://www.enticeproject.eu/		
EU Project Advisor	Narcis Paulin Jeler		
Project Coordinator	E3 Modelling S.A. (E3M)		
Deliverable	D4.1 – Reference scenario and metrics		
Work Package	WP4 – Explore the effects of trade on climate and environment		
Date of Delivery	**Contractual** 28/02/2026	**Actual**	27/02/2026
Deliverable type	Report	**Dissemination Level**	Public
Lead Beneficiary	Euro-Mediterranean Center on Climate Change (CMCC)		
Responsible Author	Elisa Delpiazzo	**Email**	elisa.delpiazzo@cmcc.it
	CMCC	**Phone**	+39 041.2346058
Contributors	Lorenza Campagnolo [CMCC]; Delpiazzo Elisa [CMCC]; Paola Rocchi [CMCC]; Lorenzo Rinaldi [POLIMI]; Esther J.M. Boere [VUA]; Marc Vielle [ORDECSYS]; Maksim Chepeliev [Purdue]; Baptiste Boitier [SEURECO]; Vassilis Daioglou [UU]		
Reviewer(s)	Natasha Frilingou [ICCS]; Chiara Forlati [UoS]; Vassilis Daioglou [UU]; Panagiotis Fragkos [E3M]; Maro Baka [E3M]; Frédéric Babonneau [ORDECSYS]		
Keywords	Scenario design, Scenario dimensions, Reference scenario, Metrics		

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

This deliverable is a public document of the ENTICE project, made available through the project website. Its primary purpose, however, is to serve as a common reference framework for scenario design and indicator selection, supporting coordination, consistency, and comparability across modelling and analytical activities in Work Packages 4 and 5. The reference scenario and metrics defined here guide subsequent model runs, scenario analyses, and result interpretation, and underpin later deliverables and external outputs.

3. Short summary of results (<250 words)

This deliverable defines a common reference scenario and a harmonised set of quantitative indicators to support the analysis of trade–industry–environment interactions within the ENTICE project. It provides a shared analytical framework to ensure coherence and comparability across modelling exercises and policy assessments conducted in Work Packages 4 and 5.

Building on inputs from a dedicated Scenario Definition Workshop conduced within ENTICE, the deliverable identifies the main dimensions shaping the trade–industry–environment nexus and organises them into a layered scenario framework. This approach enables the characterisation of critical shifts in system and the exploration of alternative trajectories that frame the outer range of plausible trajectories around the reference pathway resulting in a limited set of archetypal narratives capturing contrasting configurations of trade integration, industrial organisation, climate ambition, and enabling conditions.

The report establishes a single reference scenario reflecting recent historical trends and currently implemented climate and trade policies, anchored to the updated socioeconomic development assumptions of the SSP2 “Middle of the Road” pathway. This reference scenario serves as a neutral benchmark for assessing the impacts of alternative trade, climate, and industrial policy configurations. Key assumptions are specified for core socioeconomic drivers, selected exogenous drivers such as energy prices, extractive materials, and technology costs, and for the treatment of climate, trade, and industrial policies in the baseline.

In addition, the report proposes a structured set of indicators to describe trade patterns, industrial structures, and environmental outcomes, including greenhouse gas emissions and broader environmental pressures such as resource use, land-use change, biodiversity, and pollution. The indicators are designed to be computable from ENTICE modelling tools and to support cross-model comparison and integration. Together, these elements establish the reference framework and metrics underpinning subsequent ENTICE scenario analyses.

4. Evidence of accomplishment

This report.

Preface

In today's interconnected global economy, understanding the trade-climate nexus is more critical than ever. Trade policies significantly influence environmental outcomes, while climate change affects trade flows. However, the complex relationship between these areas remains insufficiently explored, often due to data limitations, gaps in economic modeling and the evolving nature of global supply chains. The ENTICE project aims to bridge these knowledge gaps by advancing our understanding of the trade-climate-industry (TCI) nexus. It examines how trade policies impact environmental sustainability and how climate policies shape global trade dynamics. By developing fact-based insights and innovative modeling tools, ENTICE supports informed decision-making at this crucial intersection of trade, climate, and sustainability.

E3M – E3-MODELLING AE	EL	
CMCC – FONDAZIONE CENTRO EURO-MEDITERRANEOSUI CAMBIAMENTI CLIMATICI	IT	
WI – WUPPERTAL INSTITUT FUR KLIMA, UMWELT, ENERGIE GGMBH	DE	
REFORM – FUNDACJA INSTYTUT REFORM	PL	
VUA – STICHTING VU	NL	
HOL – HOLISTIC IKE	EL	
ENEXTGEN – ENEXTGEN S.R.L.	IT	
UoS – UNIVERSITY OF SOUTHAMPTON	UK	
UNIVR – UNIVERSITA DEGLI STUDI DI VERONA	IT	
SEURECO – SEURECO SOCIETE EUROPEENNE D'ECONOMIE SARL	FR	
ICCS – EREVNITIKO PANEPISTIMIAKO INSTITOUTO SYSTIMATON EPIKOINONION KAI YPOLOGISTON	EL	
POLIMI – POLITECNICO DI MILANO	IT	
Purdue – TRUSTEES OF PURDUE UNIVERSITY	US	
ZEW – LEIBNIZ-ZENTRUM FUR EUROPAISCHE WIRTSCHAFTSFORSCHUNG GMBH MANNHEIMRL	DE	
UU – UNIVERSITEIT UTRECHT	NL	
ORDECSYS – ORDECSYS SARL	CH	

Funded by the European Union

Executive Summary

This deliverable defines the reference scenario framework and a harmonised set of quantitative indicators to be used across the ENTICE project for the analysis of trade–industry–environment interactions. It provides a common analytical foundation for modelling and policy assessments conducted primarily within Work Packages 4 and 5, ensuring coherence, comparability, and transparency across models, scenarios, and analytical approaches.

The report pursues four main objectives and activities. First, it delineates the key dimensions that structure and characterise the trade–industry–environment nexus. Second, it constructs an expanded scenario space by systematically varying these dimensions, thereby generating archetypal pathways, generalised development trajectories that synthesise recurring patterns of change and capture the principal sources of uncertainty shaping future trade, industrial, and environmental dynamics. Third, it develops a harmonised reference narrative and scenario reflecting current global conditions and the continuation of existing policy trends, including implemented climate and trade measures. Fourth, it sets out a structured suite of quantitative metrics and indicators to characterise the trade–industry–environment nexus, enabling systematic comparison of results across models, scenarios, and work packages.

The development of the scenario framework is informed by the dedicated Scenario Definition Workshop (MS9) organised within the project. The workshop brought together consortium members, Advisory Board representatives, and external experts, and combined plenary discussions with structured breakout sessions focused on trade, industry, environment, and socioeconomic drivers and enabling factors. The workshop inputs were used to identify and prioritise the dimensions most relevant for scenario design in ENTICE, including trade openness and symmetry, value chain configuration, market structure, climate policy ambition, environmental protection beyond climate, technological change, and institutional and socioeconomic enablers.

Building on these inputs, the report adopts a layered scenario approach. A single reference scenario is defined in terms of macro-dimensions to ensure tractability and alignment across modelling exercises. Around this common baseline, dimensions are further extended to explore alternative developments in trade integration, industrial organisation, climate policy ambition, and enabling conditions. By combining different configurations along these dimensions, the report defines a small number of internally consistent archetypal narratives. Within each narrative, layers are used to describe how the scenario is internally developed. These archetypes are designed to support targeted scenario and sensitivity analyses, rather than to constitute an exhaustive set of futures.

The reference scenario is anchored to the updated version of the SSP2[1], ensuring consistency with widely used global socioeconomic projections while explicitly embedding currently implemented climate and trade policies. The report discusses the treatment of core socioeconomic drivers, other key exogenous drivers (in the modelling tools) such as energy prices, extractive materials, and technology costs, and the handling of

[1] Here we consider the SSP v3.2 released in May 2025 whose data on basic drivers, such as population and GDP are downloadable at this link https://ssp.apps.ece.iiasa.ac.at/documentation/basic-drivers

climate, trade, and industrial policies within the reference framework. Particular attention is paid to maintaining internal coherence while avoiding assumptions of full global policy harmonisation.

Finally, the deliverable presents a structured indicator framework covering trade, industry, and environmental dimensions. The indicators are designed to be computable from ENTICE model outputs and to capture key mechanisms such as trade openness, global value chain participation, industrial structure, emissions, resource use, land-use change, biodiversity, and pollution. An initial mapping of indicators to models is provided, with the understanding that this mapping will be refined as modelling developments progress in the ENTICE project.

Contents

Table of Figures

Table of Tables

1 Introduction

The ENhanced understanding of Trade Impacts on Climate, industries, and the Environment (ENTICE) project is designed to advance the scientific and policy understanding of the trade–climate–industry (TCI) nexus by combining conceptual work, empirical analysis, and an enhanced modelling toolbox. A central premise of the project is that trade policies, industrial organisation, climate mitigation strategies, and broader environmental outcomes are deeply interlinked, yet are often analysed in isolation within existing modelling frameworks and scenario narratives. ENTICE addresses this gap by explicitly integrating trade and industrial dynamics into the analysis of climate and environmental transitions, with the aim of supporting more robust, transparent, and policy-relevant assessments.

Within this broader architecture, scenario design plays a foundational role. ENTICE relies on a diverse ensemble of quantitative models and analytical approaches, developed and applied across several work packages, to assess the effects of trade on emissions, resource use, biodiversity, and other environmental dimensions. Ensuring coherence and comparability across these modelling exercises requires a shared reference framework, both in terms of baseline assumptions and in terms of the indicators used to describe outcomes. Deliverable D4.1 responds to this need by defining a common reference scenario and a harmonised set of metrics and indicators for the scenario and policy analysis of the project.

This deliverable is produced under Work Package 4, which focuses on exploring the effects of trade on climate and the environment, and in particular under Task 4.1 on scenario definition. Task 4.1 is explicitly designed to provide a reference scenario and indicators to be used consistently across Work Packages 4 and 5. While WP4 applies the ENTICE modelling toolbox to quantify trade-related environmental impacts under alternative assumptions, WP5 focuses on analysing the interactions between trade, climate, and industrial policies in a broader policy context. The reference scenario and indicators defined in this report therefore serve as a shared backbone for the quantitative analyses in WP4 and for the policy-oriented assessments in WP5, ensuring that results can be interpreted within a coherent and transparent analytical frame.

The aim of this report is fourfold. First, defining the key **dimensions** that enable us to describe the trade-industry-environment nexus. Second, the report shapes a broader **scenario space**, that represents the structured set of different scenarios created by varying key dimensions in the trade–industry–environment nexus to explore how outcomes might change. Modifying key dimensions, **archetypal pathways** are produced. They are generalized, representative development trajectories that capture common patterns of change across different scenarios, simplifying complex possibilities into a small set of typical pathways that illustrate the major uncertainties and structural tensions shaping future developments in trade, industry, and environmental outcomes. Third, it establishes a **common reference narrative and scenario** that reflect the current state of the world and the continuation of recent trends, including already implemented climate and trade policies. This reference scenario provides a neutral benchmark against which the effects of alternative trade, climate, and industrial policy configurations can be evaluated using the enhanced ENTICE modelling toolbox. The reference scenario is also one "middle of the road" pathway in the scenario space. Forth, it articulates a structured set of

Funded by
the European Union

quantitative metrics and indicators to describe the trade–industry–environment nexus, enabling systematic comparison of results across models, scenarios, and work packages.

The development of this report reflects the participatory and iterative approach that characterises Task 4.1. Rather than relying exclusively on expert-driven scenario design, the development of the reference framework and scenario dimensions was informed by a dedicated **Scenario Definition Workshop** organised as part of Milestone 9. The workshop took place in September 2025 online and brought together members of the ENTICE consortium, representatives of the project's Scientific Advisory Board, and four invited external experts with complementary expertise in trade analysis, climate policy, environmental assessment, and macroeconomic modelling. This collective setting was deliberately chosen to capture a wide range of perspectives and to ensure that scenario design would reflect both modelling needs and broader policy and analytical concerns.

The workshop was conceived as an **input-gathering exercise** rather than as a decision-making forum. Its objective was not to finalise scenarios, but to identify and prioritise the key dimensions that should underpin scenario narratives within ENTICE, and to explore how these dimensions may evolve under alternative future archetypal pathways. To this end, the workshop combined plenary discussions with interactive breakout sessions structured around four macro-dimensions: trade, industry, environment, and socioeconomic drivers and enabling factors. Participants were invited to rank a set of predefined dimensions, propose additional or cross-cutting ones, and discuss how they might differ across archetypal pathways characterised by varying degrees of trade openness, industrial organization, and climate ambition.

Insights from the workshop play a central role in this deliverable. They inform the identification of the **core dimensions** shaping the ENTICE scenario space, the construction of archetypal pathways around the reference scenario, and the selection of metrics used to characterise trade-related environmental outcomes. Importantly, the workshop also highlighted the need to move beyond traditional scenario frameworks in which trade is treated as an implicit background variable. Instead, participants consistently emphasised the importance of explicitly representing trade openness, value-chain configuration, market structure, and policy fragmentation as central elements of scenario narratives, alongside climate ambition and environmental protection.

Building on this collective input, the report adopts a **layered approach to scenario design**. A **single reference scenario** is defined to ensure tractability and consistency across modelling exercises, while shifts in key dimensions are introduced to capture critical shifts in system dynamics (i.e., turning points) and to explore **alternative trajectories** that frame the outer range of plausible developments around the reference pathway (i.e. boundary pathways). These dimensions are organised along the main macro-dimensions identified during the workshop and give rise to a limited set of **archetypal narratives** that capture contrasting configurations of trade integration, industrial organisation, climate policy ambition, and enabling conditions. This approach allows ENTICE to explore **uncertainty** and structural change without proliferating reference scenarios, while still providing a rich conceptual space for targeted scenario and sensitivity analyses.

In parallel, the report develops a harmonised set of **indicators** intended to describe the trade–industry–environment nexus in a systematic and comparable way. The indicator framework is designed to be operational across the diverse modelling tools used in ENTICE and to cover not only greenhouse gas emissions, but also broader environmental pressures such as resource extraction, land-use change, biodiversity, and pollution. By providing a shared set of metrics, the report supports cross-model scenario comparison, integration of results across work packages, and communication of findings to policy and stakeholder audiences.

Overall, this deliverable constitutes a foundational element of the ENTICE analytical framework. It establishes the common reference points needed to align qualitative narratives, quantitative modelling, and policy analysis across the project, and creates the conditions for coherent interpretation of results in subsequent deliverables. By embedding scenario design in a collective and transparent process, and by explicitly placing trade at the centre of the climate–environment discourse, D4.1 sets the stage for the empirical and policy-oriented analyses that follow in WP4 and WP5.

2 The Need for a Shared Terminology in Scenario design

Designing a scenario framework is a powerful method for exploring uncertainty, aligning stakeholders, and guiding long-term strategic decisions. Despite its versatility, one recurring challenge undermines the effectiveness of scenario exercises: the absence of a shared and clearly defined terminology.

A scenario design typically brings together participants from diverse disciplines, sectors, and epistemological backgrounds that may all interpret core terms, such as scenario, pathway, assumption, driver, layers, in subtly different ways. Without explicit alignment on terminology, discussions risk becoming conceptually fragmented, creating ambiguity, reducing analytical rigor, and compromising the credibility of the final outputs.

A shared terminology serves several essential functions. First, it enhances conceptual clarity. Clear definitions delineate what a scenario is and what it is not. Second, common language strengthens methodological consistency. Third, a shared vocabulary fosters effective collaboration. Scenario exercises are inherently dialogical and iterative. Common terminology reduces friction, minimizes misinterpretation, and supports productive disagreement. It enables participants to focus on substantive strategic questions rather than clarifying basic concepts mid-process. Finally, shared terminology improves external communication and comparability. Scenario frameworks often inform policy debates, investment decisions, or public discourse. When terms are clearly defined and consistently applied, stakeholders outside the design team can better interpret and evaluate the results. Moreover, alignment with established terminology in international or sectoral communities enhances interoperability and cumulative learning across exercises.

In sum, a shared and common terminology is not a peripheral concern in scenario framework design; it is foundational. It creates the conceptual infrastructure upon which meaningful exploration of uncertainty can occur. Here we provide a brief description of the main concepts used and applied in the ENTICE scenario design. Firstly, we distinguish the concepts of narrative and scenario as well as scenario space and archetypal pathways.

- **Narrative.** It is a structured, coherent qualitative story, or storyline, that describes how and why a sequence of events unfolds over time. In scenario work, a narrative connects drivers, decisions, uncertainties, and consequences into a meaningful account of change.
- **Scenario.** It is a coherent, internally consistent quantitative and qualitative description of a possible future. It represents one specific combination of conditions along the key dimensions, assumptions, and drivers of the system being studied.
- **Scenario Space.** It is a structured set of different scenarios created by varying key factors, assumptions, or uncertainties to explore how outcomes might change.
- **Archetypal pathways.** They are generalized, stylized trajectories of system development that represent recurrent patterns of change across multiple scenarios or contexts.

Then, within each scenario we identify a series of constitutive elements.

- **Macro-dimension**. It is a high-level structural axis of variation that captures a fundamental domain of change within a scenario space. It represents a broad system-shaping category, in our case they are trade, industry, the environment, and socioeconomic drivers and enablers. Macro dimensions define the major structural features of the system under analysis and serve as organizing pillars for differentiating scenarios.

- **Dimension.** It is an analytical axis of variation used to structure a scenario space and differentiate alternative futures. It represents a key variable, uncertainty, or structural feature along which scenarios meaningfully differ. A dimension defines *how* the future can vary, providing the internal coordinates that organize possible configurations within that scenario space.
- **Layer.** It is a structured level of analysis within a scenario framework that organizes related elements of the system according to their functional role, scale, or degree of abstraction. Layers represent the plane along different pathways defined by a specific dimension (dimension layer) and varying levels of analytical depth (analytical layer), while preserving the connections between them.
- **Driver.** It is a factor, force, or process that influences the direction, pace, or character of change within a system over time. Drivers are the underlying sources of transformation that shape how alternative futures may unfold.
- **Assumption**. It is an explicit statement about a condition, relationship, or future development that is provisionally accepted as true within a scenario in order to structure analysis and ensure internal consistency. In scenario design, assumptions define the foundational premises upon which scenarios are built. They clarify what is being held constant, what is allowed to vary, and what contextual conditions are taken as given.
- **Metrics.** They are measurable indicators used to track, quantify, and evaluate key aspects of a scenario. They provide concrete, often quantitative, ways to assess the implications, progress, or plausibility of different futures. They translate abstract narratives and drivers into observable outcomes, allowing comparison, monitoring, and communication.

3 Collecting input for scenario design

The definition of scenarios within the ENTICE project builds on the recognition that the interactions between trade, industry, climate, and the environment are characterised by deep uncertainty, structural change, and strong interdependencies across policy domains. Traditional scenario frameworks often treat trade as an implicit background variable, while climate and environmental dimensions are analysed in relative isolation from industrial organisation and global value chains (O'Neill et al., 2014, 2017; Riahi et al., 2017; Popp et al., 2017). Against this backdrop, ENTICE adopts a scenario design approach that explicitly places the trade–industry–environment nexus at the centre of the analytical framework.

In this context, the **Scenario Definition Workshop**[2] was conceived as a dedicated moment of collective reflection aimed at supporting the early stages of scenario development in the project. Rather than defining a complete set of scenarios, the workshop focused on identifying the **key dimensions** that should underpin scenario narratives in ENTICE, exploring their relevance for the **trade–industry–environment nexus**, and discussing how these dimensions may evolve across alternative future worlds. The workshop was therefore intended as an input-gathering exercise, designed to inform subsequent modelling and analytical work, rather than as a decision-making forum.

The workshop took place online on 22 September 2025 and brought together 69 participants, including members of the ENTICE core project team (n=49), representatives of the project's Scientific Advisory Board (n=3), and external experts (n=17) (Figure 1). The project members contributed their multidisciplinary expertise (e.g. economics, climate policy, environmental assessment, trade analysis, and modelling), which is reflected in the interdisciplinary nature of the project. External participants represented potential stakeholders interested to the projects' outcome and belonged to the academia (18%), think tank (29%), ONG with environmental advocacy (6%), public institutions (35%, equally spread between national and EU levels), and industry associations (12%). The diversity of disciplinary backgrounds and institutional affiliations fostered a comprehensive exchange of views, enabling the early integration of stakeholder perspectives into the scenario definition that ultimately will affect the project's analytical and policy-oriented work. While most participants were based in Europe, the workshop also included representatives of international organisations and institutions with a global analytical scope, including multilateral organisations and non-EU universities. This ensured that the discussion extended beyond an exclusively EU perspective and considered broader global trade dynamics.

[2] For a detailed description of the outcome of the Workshop and its minutes, see Milestone MS9.

Funded by the European Union

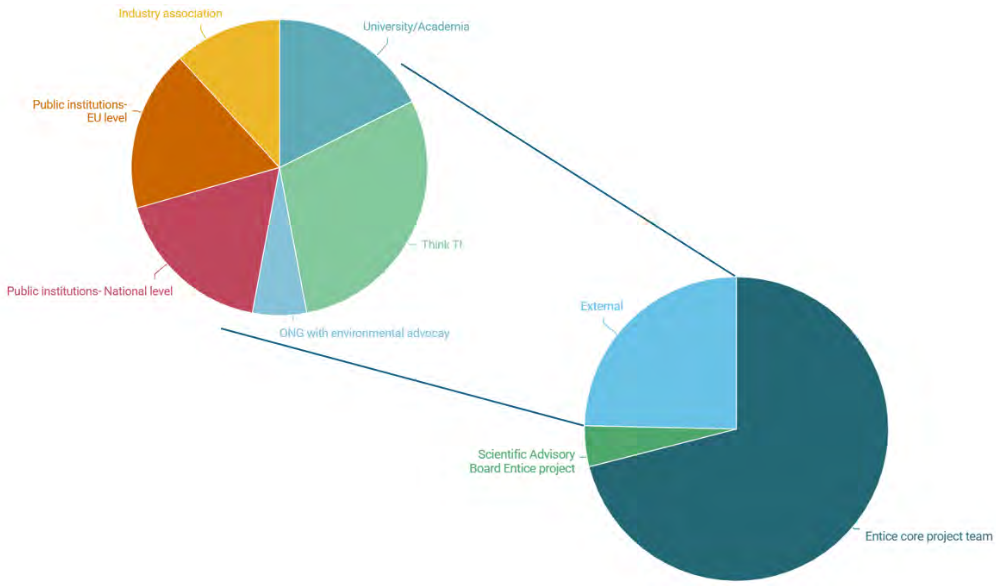

Figure 1: Composition of the audience at the Scenario Definition Workshop and sectors of external participants.

The overall **objective of the workshop** was to collect structured input on scenario design along three main lines. First, it aimed to explore how **trade** can be more explicitly and systematically integrated into scenario narratives, both as a driver of environmental outcomes and as a dimension affected by climate and environmental policies. Second, it sought to identify and prioritise the **dimensions** that are most relevant for describing alternative futures at the intersection of trade, industry, and the environment, paying particular attention to structural features such as market organisation, value chain configuration, and resource availability. Third, the workshop aimed to reflect on the nature of **uncertainty** in this space, including the role of geopolitical developments, policy fragmentation, and technological change, and on how such uncertainty can be meaningfully represented in scenario frameworks.

To support these objectives, the workshop was structured into a combination of plenary and break-out sessions (see Annex A for the detailed agenda). The first part of the workshop consisted of a **plenary session** with four invited keynote speakers, who provided high-level perspectives on scenario design and on key challenges related to the trade–climate–industry nexus. Richard Baron (European Climate Foundation) brought expertise in strategic climate foresight and international climate governance, drawing on his experience in supporting long-term decarbonisation strategies and policy coordination across jurisdictions. Antoine Oger (Institute for European Environmental Policy) contributed perspectives on the sustainability impacts of trade agreements and on the integration of environmental objectives within EU trade and external policies. Eddy Bekkers (World Trade Organization) provided insights grounded in quantitative trade modelling and WTO analytical work, with a focus on the interaction between trade policies, global value chains, and environmental outcomes. Cecilia Bellora (OECD) shared expertise in applied general equilibrium modelling of trade and environmental policies, particularly in relation to carbon leakage and border carbon adjustment mechanisms.

Together, these contributions ensured coverage of complementary analytical and policy perspectives, providing a structured basis for the subsequent discussion on how trade, climate, and industrial dynamics can be more systematically integrated within scenario frameworks. These interventions were intended to set the scene for the subsequent discussions, highlight emerging issues, and stimulate reflection on how existing scenario frameworks may need to be extended or adapted.

The second part of the workshop was organised around a set of **parallel breakout sessions**, each focusing on a specific macro-dimension relevant for scenario design in ENTICE. Four breakout groups were defined, covering **trade**, **industry**, **environment**, and **socioeconomic drivers and enabling factors**. Within each breakout session, participants engaged in a guided exercise aimed at ranking a set of predefined key dimensions according to their relevance for describing each macro-dimension, identifying missing or cross-cutting elements, and discussing how these dimensions could be characterised under different future configurations. This structure was chosen to allow for in-depth discussion within macro-dimensions, while maintaining comparability across groups.

The design of the workshop reflected a deliberate balance between structure and openness. On the one hand, predefined dimensions and guiding questions were used to ensure that discussions remained focused and that outputs could be systematically compared across breakout groups. On the other hand, participants were encouraged to challenge the initial framing, propose additional dimensions, and reflect critically on the limitations of existing scenario approaches. This combination was intended to capture both convergence and divergence in stakeholders' perspectives, and to surface areas of agreement as well as sources of uncertainty and debate.

Importantly, the workshop was not conceived as an isolated activity, but as part of a broader iterative process of scenario development within ENTICE Task4.1. The insights gathered during the workshop were expected to feed directly into the definition of the reference scenario and the identification of key indicators, while also informing the design of alternative scenario layers and sensitivity analyses to be explored in subsequent work packages. In this sense, the workshop represents a foundational step in aligning qualitative narratives, expert judgement, and quantitative modelling within a coherent scenario framework.

3.1 Framing scenario design: insights from the Mentimeter exercise

As an introductory step to the Scenario Definition Workshop, participants were invited to take part in an interactive **Mentimeter** exercise aimed at eliciting their immediate perceptions and associations with the concept of scenario design. The purpose of this exercise was to provide a qualitative snapshot of how scenario design is perceived across the diverse disciplinary and professional backgrounds represented in the workshop, and to set the tone for the subsequent, more structured discussions.

Participants were asked to list up to four keywords that they associate with scenario design. The exercise received a high level of engagement, with 39 participants contributing responses and an average of 3.5 keywords submitted per respondent. The resulting word cloud reveals a strong convergence around a limited set of core concepts, indicating a relatively shared understanding of the role and nature of scenario design within the group. Figure 2 reports the results.

Funded by
the European Union

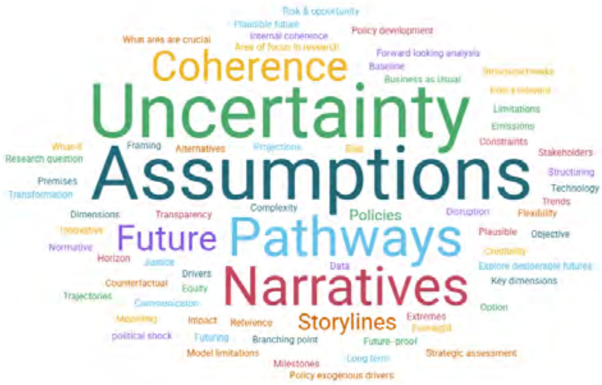

Figure 2. Word clouding for Mentimeter poll exercise

Among the most frequently cited terms were "***assumptions*** and "***uncertainty***". Their prominence reflects a widespread recognition that scenario design fundamentally involves making assumptions explicit and confronting uncertainty in a structured way. Rather than seeking to predict future outcomes, scenarios are understood as tools for exploring a range of plausible futures under different sets of assumptions. This perspective aligns with the use of scenarios as exploratory and stress-testing instruments, particularly in policy-relevant contexts characterised by deep uncertainty and limited foresight.

Closely related to this, the terms "***pathways***" and "***narratives***" also featured prominently in the responses. These keywords highlight the importance attributed to the storytelling dimension of scenario design, whereby scenarios are constructed as coherent narratives that describe how the world might evolve over time. The emphasis on pathways suggests an understanding of scenarios as dynamic processes, focusing on trajectories and transitions rather than on static end states. Narratives, in turn, are seen as a means of linking assumptions, drivers, and outcomes into internally consistent and communicable storylines.

Another term that emerged frequently in the Mentimeter exercise was "***coherence***". This reflects a strong concern among participants for internal consistency within scenarios, both in terms of logical structure and in terms of alignment between qualitative narratives and quantitative representations. Coherence was understood not only as avoiding internal contradictions, but also as ensuring that scenarios remain credible and interpretable for both modelling exercises and policy discussions. In this sense, coherence is viewed as a prerequisite for meaningful comparison across scenarios and for the integration of results across different analytical tools.

In addition to these core concepts, several responses pointed to the broader purpose and scope of scenario design. Keywords such as "*future*", "*policy*", "*exploration*", and "*decision-making*" indicate that participants see scenarios as forward-looking tools that support strategic thinking and policy analysis. Scenario design was thus not framed primarily as a technical modelling exercise, but rather as a process that helps structure thinking about long-term developments, identify potential risks and opportunities, and assess the implications of different policy choices under alternative conditions.

Funded by
the European Union

The diversity of keywords also reflects the interdisciplinary nature of the workshop. Participants coming from modelling backgrounds tended to emphasise assumptions, coherence, and pathways, while those with policy or qualitative research experience more often highlighted narratives, futures, and decision-making. Despite these differences, the overall distribution of responses suggests a substantial degree of alignment across perspectives, providing a common conceptual ground for the subsequent stages of the workshop.

Taken together, the Mentimeter exercise confirms that scenario design within ENTICE is widely understood as an exercise that combines explicit assumptions, structured treatment of uncertainty, and coherent narratives to explore alternative future pathways. This shared understanding provided a useful starting point for the more detailed examination of specific dimensions and drivers carried out in the plenary and breakout sessions that followed.

3.2 Key messages from the plenary session

The plenary session of the Scenario Definition Workshop was designed to provide a high-level conceptual framing for the subsequent discussions, bringing together perspectives from invited keynote speakers with complementary expertise on scenario design, trade, climate policy, macroeconomic modelling, and industrial dynamics. The plenary interventions highlighted a set of recurring themes that are directly relevant for the development of scenario narratives within ENTICE, particularly with respect to the role of trade and its interaction with climate and environmental outcomes.

A first key message emerging from the plenary session concerns the role of scenarios as tools for dealing with **deep uncertainty** rather than as predictive instruments. Speakers consistently emphasised that scenarios should not be interpreted as forecasts of the most likely future, but as structured representations of alternative pathways that allow analysts to explore how different assumptions, policy choices, and external conditions may shape future outcomes. In this sense, scenario design was framed as an exercise in transparency, aimed at making underlying assumptions explicit and at clarifying the conditions under which particular results will emerge.

Several speakers underlined that current global developments make this approach particularly relevant. The international context is characterised by heightened geopolitical tensions, increasing fragmentation of trade relations, increasing political uncertainty, and diverging national strategies with respect to climate and industrial policy. These dynamics introduce forms of uncertainty that cannot be easily captured through the extrapolation of historical trends. As a result, scenario narratives need to be sufficiently flexible to accommodate discontinuities, reversals, non-linearities and asymmetric developments across regions and sectors.

A central focus of the plenary discussion was the multifaceted relationship between **trade and climate outcomes**. Trade was described as both a driver of environmental impacts and a channel through which climate policies propagate across borders. On the one hand, trade affects emissions through transport activity, changes in production location, and differences in emission intensities across countries and firms. On the other hand, climate policies influence trade patterns by altering relative prices, competitiveness, and market access, potentially leading to phenomena such as carbon leakage or the reconfiguration of global value chains.

Speakers highlighted that these interactions operate through multiple and sometimes counteracting **channels**. For example, increased trade openness may lead to higher transport emissions, but it can also facilitate the diffusion of cleaner technologies and allow production to relocate to regions with higher efficiency, lower emission intensities or abundant low-carbon energy. Similarly, stricter climate policies may reduce domestic emissions while increasing imports from less regulated regions, unless accompanied by complementary measures, such as carbon border adjustments. These considerations underscore the importance of analysing trade and climate jointly, rather than treating them as separate policy domains.

Another recurring theme in the plenary session was the role of **firms and market structure** in shaping trade–climate interactions. Several speakers pointed out that exporting firms tend to be larger, more productive, and often cleaner than firms serving only domestic markets. This implies that trade liberalisation and restriction can have heterogeneous effects across firms, with implications for aggregate emission intensities and competitiveness. At the same time, differences in market structure, such as the degree of concentration or the presence of dominant players, influence investment decisions, technology adoption, and the ability of firms to absorb policy-induced cost increases.

The discussion also emphasised the growing importance of **global value chains** and their vulnerability to shocks. Climate change itself was identified as a source of disruption to trade, through its impacts on infrastructure, logistics, and production systems. Extreme weather events, water scarcity, and changes in land productivity can affect key nodes in global supply chains, with cascading effects across regions and sectors. These considerations suggest that future trade patterns may be shaped not only by policy choices but also by physical climate impacts, adding another layer of complexity to scenario design.

With respect to climate policy, several speakers stressed that globally harmonised solutions, such as a uniform global carbon price, remain largely theoretical. In practice, **climate policies** are implemented in a **fragmented and heterogeneous** manner, reflecting differences in national priorities, institutional capacity, and political constraints. This heterogeneity creates spillovers across borders and raises challenges for international coordination. As a result, scenarios that assume full global harmonisation may be useful as benchmarks but are unlikely to represent plausible reference pathways in the near to medium term.

Related to this, the plenary discussion highlighted the increasing relevance of **unilateral and plurilateral measures**, such as border carbon adjustments, climate clubs, and preferential trade arrangements linked to environmental standards. These instruments blur the boundary between trade and climate policy, and their potential expansion raises important questions about future trade regimes, competitiveness, and equity. Speakers noted that such measures could lead to selective cooperation among groups of countries, rather than to uniform global outcomes, further reinforcing the need for scenario narratives that go beyond simple dichotomies between free trade and protectionism.

A further point raised during the plenary session concerns the **limitations of traditional reference scenarios**. Several speakers argued that baselines based on “no policy” assumptions are increasingly detached from reality, given the widespread presence of climate, environmental,

Funded by
the European Union

and industrial policies across countries. Even in the absence of explicit carbon pricing, many policies implicitly affect emission intensities and production choices. Reference scenarios therefore need to reflect a world in which policies are already in place, while acknowledging uncertainty about their future evolution and effectiveness.

In this context, existing global scenario frameworks, such as the **Shared Socioeconomic Pathways** (SSPs), were recognised as valuable **starting point** but also as incomplete representations of the trade–climate–industry nexus. Speakers suggested that SSP-based narratives could be enriched by incorporating more explicit assumptions on trade openness, value chain configuration, industrial organisation, and policy interaction. This enrichment was seen as particularly important for projects like ENTICE, which aim to analyse the environmental implications of trade and industrial policies in a systematic way.

Overall, the plenary session provided a set of conceptual anchors for the subsequent work on scenario definition within ENTICE. By highlighting the central role of uncertainty, the multiple channels linking trade and climate, and the limitations of existing baselines, the plenary discussion helped clarify the analytical challenges that the project seeks to address. These insights inform both the design of the reference scenario and the broader scenario space explored in the following sections of this deliverable.

3.3 Main outputs from the breakout sessions

The second part of the Scenario Definition Workshop was organised around four parallel breakout sessions, each focusing on a core macro-dimension relevant for the trade–industry–environment nexus: trade, industry, environment, and socioeconomic drivers and enabling factors. The breakout sessions were designed to elicit detailed and macro-dimension specific input in a structured yet open-ended manner, allowing participants to collectively reflect on the dimensions that should underpin narratives within ENTICE.

Each breakout group followed the same three-step exercise. First, participants were asked to rank a predefined list of **dimensions** according to their relevance for analysing interactions between trade, industry, climate, and the environment. Second, they were invited to identify additional dimensions that they considered missing, insufficiently represented, or cross-cutting across domains. Third, participants were asked to discuss how the most relevant dimensions would be characterised under a set of **illustrative narratives**, defined along two broad axes: the degree of trade openness and the level of climate ambition. This common structure ensured comparability across breakout groups while allowing for in-depth discussion within each domain.

To guide the breakout discussions and ensure comparability across thematic groups, participants were provided with a common set of predefined dimensions for each macro-dimension. These dimensions were intended as a structured starting point for the ranking exercise and for the subsequent identification of missing or cross-cutting elements, while leaving participants free to challenge and extend the initial framing. Table 1 summarises the full list of dimensions that were made available to participants across the four breakout sessions.

Table 1. Predefined dimensions used in the breakout sessions

Macro-dimensions	Dimensions	Definition
Trade	Trade openness	Degree to which a country relies on international trade, commonly measured as trade-to-GDP ratio.
	Domestic market size	Influence of country size on reliance on international trade, with smaller markets typically resulting in greater trade dependence.
	Type of tradables	Extent to which a country's trade is dominated by commodities, services, or manufactured goods.
	Trade value chain	Structure of trade flows along global value chains, including upstream and downstream positioning.
	Trading routes	Main modes and routes of trade such as sea, land, or air, shaping the movement of goods across regions and countries.
	Trade partner composition	Degree of concentration or diversification of trade partners.
	Transport and infrastructure	Systems and facilities that enable efficient movement of goods, influencing costs, delays, and market access.
	Trade regulations and policies	National and international rules governing trade, including tariffs, quotas, standards, and cross-border flows.
	Trade agreements	Bilateral, multilateral, or regional agreements that reduce trade barriers and harmonise rules.
	Technology transfer and diffusion	Transmission of technologies through trade, standards, and cooperation, generating spillovers and supporting productivity growth.
Industry	Market structure	Organisation of markets such as competitive markets, oligopolies, or monopolies, and associated concentration levels.
	Market competition intensity	Degree of competition among firms within the same industry.
	Firm heterogeneity	Differences across firms in size, productivity, cost structures, innovation capacity, and strategic behaviour.
	Barriers to entry or exit	Obstacles that prevent firms from entering or exiting markets, including regulatory, technological, and institutional factors.
	Spatial configuration	Geographical location of manufacturing and service activities.
	Global value chain integration	Position of firms and sectors within global value chains, including vertical and horizontal specialisation.
	Innovation and technology adoption	Role of innovation in driving competitiveness, efficiency, and environmental performance.
	Industrial policies	Policy measures shaping industrial dynamics, influencing spatial configuration, production, and technological change.
Environment	GHG emissions	Greenhouse gases released into the atmosphere that contribute to climate change.
	Carbon intensity of production	Emissions per unit of output.
	Energy and resource	Use of energy and material resources across extraction,

	consumption	conversion, distribution, and end use.
	Pollution	Release of harmful substances into air, water, and soil, affecting ecosystems and human health.
	Extraction and processing of critical raw materials	Activities related to mining, refining, and preparing essential minerals and materials.
	Land-use change	Conversion of land for agriculture, urban development, or infrastructure.
	Biodiversity	Variety and variability of living organisms and ecosystems.
	Circular economy	Economic system aimed at minimising waste and resource use through reuse, recycling, and recovery.
	Environmental regulation and mitigation policy	Policies and measures aimed at protecting the environment and reducing environmental damage.
Socioeconomic drivers, enabling factors	Population and demographic	Size and characteristics of the population such as age, gender, and income.
	Economic development	Process of improving economic, social, and institutional well-being.
	Technological development	Creation, improvement, and diffusion of technologies across economic and industrial activities.
	Education and human capital	Acquisition of knowledge, skills, and abilities that enhance productivity and social outcomes.
	Cultural and social dynamics	Social structures, preferences, and norms influencing behaviour and decision-making.
	Natural resource endowments and depletion	Availability and use of natural resources, including extraction and environmental degradation.
	Financial enablers	Access to finance, credit, investment, and risk-sharing mechanisms.
	Technological and structural transformations	Economy-wide shifts driven by innovation, digitalisation, and changes in sectoral composition.
	Institutional governance	Formal and informal rules, organisations, and processes guiding economic and political interactions.
	Political economy dynamics	Interactions between political decisions, resource allocation, and reform implementation.

Trade breakout session

In the trade-focused breakout session, participants consistently identified **trade openness** as a foundational dimension shaping the intensity and nature of interactions across the trade–industry–environment nexus. Trade openness was discussed not only in terms of aggregate trade-to-GDP ratios, but also in relation to the composition of trade, the structure of trading partners, and the exposure of domestic economies to external shocks. Participants noted that economies with higher levels of trade openness tend to be more sensitive to changes in trade and climate policies, as well as to disruptions in global supply chains.

Closely linked to trade openness, **trade regulation** emerged as another highly relevant dimension. Participants emphasised that modern trade regulation extends well beyond tariffs, encompassing non-tariff measures, technical standards, regulatory cooperation, and provisions embedded in preferential trade agreements. These elements were seen as particularly important for environmental outcomes, as they directly affect production processes, technology choices, and compliance costs. The discussion highlighted that differences in regulatory frameworks across countries can create both barriers and incentives for cleaner production, shaping trade patterns in ways that are not captured by price-based measures alone.

Global value chain structure and **resilience** were also ranked as critical dimensions. Participants stressed that the degree of fragmentation of value chains affects vulnerability to shocks, the transmission of policy impacts, and the distribution of environmental burdens along production stages. Highly fragmented global value chains were associated with increased exposure to disruptions, including those arising from climate-related events, geopolitical tensions, or sudden policy changes. At the same time, value chain fragmentation was recognised as a source of efficiency gains and specialisation, raising questions about trade-offs between resilience, competitiveness, and environmental performance.

Several additional dimensions were proposed during the trade breakout discussion. These included the role of **transport and logistics infrastructure**, the **environmental footprint** of shipping and aviation, and the **reconfiguration of trade routes** in response to climate policies or physical climate impacts. Participants also highlighted the importance of trade partner composition, noting that shifts towards more regional or politically aligned trade relationships could have significant implications for emissions, technology diffusion, and resource use.

Industry breakout session

The industry-focused breakout session concentrated on dimensions related to **production organisation, market structure, and technological change**. Market structure emerged as a central dimension, with participants emphasising the role of concentration, firm size distribution, and market power in shaping industrial responses to trade and climate policies. Highly concentrated industries were seen as having greater capacity to absorb policy-induced cost increases and to invest in cleaner technologies, but also as potentially slower to adjust due to incumbent advantages and lock-in effects.

Global value chain integration was again highlighted as a key dimension, this time from the perspective of industrial organisation. Participants discussed how firms' positioning along value chains influences their exposure to trade restrictions, carbon costs, and supply disruptions. Industries heavily reliant on imported intermediate inputs were seen as particularly sensitive to changes in trade policy and transport costs, while more vertically integrated or domestically oriented industries may face different adjustment challenges.

The **spatial configuration** of production was identified as another crucial element. Participants noted that the geographical distribution of industrial activity affects both competitiveness and environmental outcomes, given differences in access to infrastructure, energy systems, labour markets, and natural resources. The potential relocation of energy-intensive industries towards regions with abundant low-cost renewable energy was discussed as a plausible response to increasing climate ambition, with implications for trade flows and regional development.

Funded by
the European Union

Innovation and technology adoption were consistently ranked among the most important dimensions in the industry breakout session. Participants emphasised that technological change shapes emission intensities, resource efficiency, and long-term competitiveness, and interacts strongly with both trade and climate policies. Differences in innovation capacity and diffusion rates across countries and sectors were seen as major drivers of divergence in future industrial pathways.

Industrial policy was extensively discussed, but participants generally agreed that it should be treated as a cross-cutting dimension rather than as a standalone one. Measures such as subsidies, public investment, and strategic planning influence multiple aspects of industrial organisation simultaneously, including market structure, technology adoption, and spatial configuration. As a result, industrial policy was viewed as an underlying force that shapes how other dimensions evolve, rather than as an independent dimension of scenario differentiation.

Environment breakout session

The environment-focused breakout session placed **greenhouse gas emissions** at the centre of the discussion, identifying them as a primary outcome dimension for scenario analysis. Participants emphasised the importance of distinguishing between aggregate emission trajectories and sectoral or regional contributions, particularly in the context of trade-induced emission transfers and carbon leakage. Emission intensity, both in production and in consumption terms, was highlighted as a key metric for capturing environmental performance.

Beyond climate mitigation, participants stressed the need to incorporate a broader set of environmental dimensions into scenario narratives. **Land-use change**, **biodiversity loss**, and the **extraction and processing of critical raw materials** were repeatedly identified as areas where trade and industrial dynamics play a significant role. Participants noted that these environmental pressures may not evolve in parallel with greenhouse gas emissions, and that scenarios focused exclusively on carbon risk overlooking important trade-offs and co-benefits.

Additional dimensions proposed during the environment breakout session included **pollution**, **waste generation**, and **marine impacts**, particularly those associated with shipping and offshore activities. The environmental consequences of **mining and material extraction** were also discussed, especially in the context of increased demand for critical raw materials driven by the energy transition. These discussions highlighted the interconnected nature of environmental challenges and the importance of considering cumulative impacts across domains.

Participants also emphasised that environmental outcomes are shaped not only by **policies** but also by **structural features of production and consumption systems**. As a result, environmental dimensions were generally framed as outcome-oriented, reflecting the combined effects of trade patterns, industrial organisation, technological change, and policy frameworks, rather than as direct proxies for specific regulatory instruments.

Socioeconomic drivers and enabling factors breakout session

The breakout session on socioeconomic drivers and enabling factors focused on background conditions that shape the feasibility and effectiveness of different pathways. **Technological development** emerged as a central driver, with participants highlighting the role of innovation capacity, learning processes, and diffusion dynamics in enabling structural transformation. Differences in technological trajectories across regions were seen as a key source of divergence in future outcomes.

Natural resource endowments and availability were also identified as important enabling factors, influencing both trade patterns and industrial specialisation. Participants discussed how access to energy resources, critical minerals, and land can shape comparative advantages and constrain or enable decarbonisation pathways. **Financial capacity and access to capital** were highlighted as additional enablers, affecting the ability of firms and governments to invest in new technologies and infrastructure.

Institutional and governance capacity featured prominently in the discussion, although participants acknowledged the challenges associated with operationalising these dimensions in quantitative models. **Governance quality, policy coherence, and administrative capacity** were nevertheless seen as critical determinants of how effectively policies are implemented and how societies respond to shocks.

Geopolitical dynamics and distributional considerations were also discussed as cross-cutting factors influencing future pathways. Participants noted that geopolitical tensions can affect trade relations, technology transfer, and resource access, while distributional outcomes influence political support for trade and climate policies. These dimensions were recognised as important sources of uncertainty and potential disruption, reinforcing the need for scenario frameworks that can accommodate non-linear changes and asymmetric developments.

Overall, the breakout sessions provided a rich and detailed set of inputs on the dimensions that should underpin scenario narratives in ENTICE. While each breakout group emphasised different aspects of the trade–industry–environment nexus, there was broad agreement on the importance of capturing structural features, interactions across macro-dimensions, and policy uncertainty. These insights directly inform the definition of the scenario space, the choice of the reference narrative and scenario, and the selection of indicators presented in the subsequent sections of this deliverable.

Funded by
the European Union

4 From scenario dimensions to archetypal narratives

This section translates the dimensions identified through the Scenario Design Workshop into a structured scenario space for the ENTICE project. Building on the workshop outcomes, we move from a list of relevant dimensions to a representation of alternative future pathways laying in a scenario space, organised around key dimensions in the trade–industry–environment nexus. The objective is not to define an exhaustive set of scenarios, but to characterise a limited number of internally consistent and analytically meaningful pathways that capture contrasting configurations of trade integration, industrial organisation, climate ambition, and enabling conditions. These pathways provide a conceptual structure for subsequent modelling and analytical work and help situate the reference scenario within a broader space of possible futures.

This section is organised as follows. Section 4.1 introduces the layered scenario design and describes the key dimensions shaping the trade–industry–environment nexus, structured around trade, industry, environmental outcomes, and enabling factors. Section 4.2 builds on these dimensions to define a limited set of archetypal pathways, outlining their main characteristics and internal logic. Section 4.3 then discusses how these archetypes can further be enriched by adding guidelines for quantitative modelling within the ENTICE framework.

4.1 Scenario design and key dimensions of the trade–industry–environment nexus

This section defines and explores the **ENTICE scenario space**, combining the critical dimensions listed in Table 1 and refined during the Scenario Design Workshop. The **key dimensions** in the trade–industry–environment nexus can be viewed either as factors that trigger major turning points or as layers that accumulate to shape possible future trajectories (**dimension layer**); this section focuses on the idea of layers formed when shifts in the quantitative value of a dimension generate new **future pathways** in the scenario space.

Within this scenario space, the **reference scenario** corresponds to a central trajectory against which more divergent future pathways can be characterised. In this section, our attention shifts to the **boundary future pathways**, where we begin to sketch out their shape and characteristics, gradually revealing them as archetypal pathways about how the future might unfold.

The introduction of layers responds to the need to reconcile two competing requirements. On the one hand, ENTICE relies on a single reference scenario as a common point of comparison across analyses. On the other hand, discussions during the workshop and subsequent exchanges highlighted the rapidly increasing uncertainty surrounding climate policies, trade policies, and their interaction, driven by geopolitical fragmentation, policy volatility, and heterogeneous transition strategies. The layer-based approach provides a structured way to capture this uncertainty without multiplying reference scenarios, by explicitly characterising key turning points around the reference trajectory. Mapping these archetypal pathways will help us define and understand the space surrounding the reference scenario and will be instrumental for the modelling tasks in WP4.

We will focus on each of the macro-dimensions (trade, industry, environment, and enablers), examine the relevant dimensions identified during the Scenario Workshop, add additional

Funded by
the European Union

dimensions that emerged as necessary to characterise paths, and represent them in a branching structure that illustrate the range of archetypal pathways. While these macro-dimensions are presented separately for clarity, they will be combined at the end into alternative narrative configurations. Without aiming to be exhaustive, the project will identify a limited set of relevant and internally consistent combinations to support targeted modelling and analytical exercises.

The first macro-dimension we consider in our setting relates to **trade** and captures shifts along two dimensions, i.e. **trade-openness** (a) and **degree of trade symmetry** (b) (Figure 2). The **trade-openness dimension** ranges from a free-trade scenario to a more restricted one. Trade openness or restriction is typically shaped by trade regulation and policy. While trade policy is therefore central to determining trade outcomes, we treat it here as an instrument rather than as a standalone dimension and focus instead on the resulting degree of openness as the relevant state variable for scenario characterisation.

To better characterise trade liberalisation/restriction, a second dimension is introduced, capturing the **degree of trade symmetry**. Under liberalised trade regimes, the degree of symmetry produces alternative institutional configurations, such as global multilateral cooperation versus more regional or preferential arrangements, which give rise to distinct narratives with different implications for market access, supply chains, and exposure to external shocks. In a trade regime characterized by trade restriction, the degree of symmetry indicates the reciprocity of the restrictions that can be symmetric and equal, in the case of autarky, and asymmetric and differentiated in the case of a fragmented trade. Further layers could be introduced by exploiting, for instance, the "*type of tradables*" dimension, allowing finer representation of trade configurations and policies that specifically target key sectors such as steel, aluminium and pharmaceuticals.

In the characterisation of trade, we also omit the technology transfer and diffusion dimension, as we consider it to affect all macro-dimensions. We therefore prefer to treat it as part of the enabling factors rather than as a standalone dimension. Figure 3 highlights the pathways that can arise by the combination of the two dimensions in the trade macro-dimension.

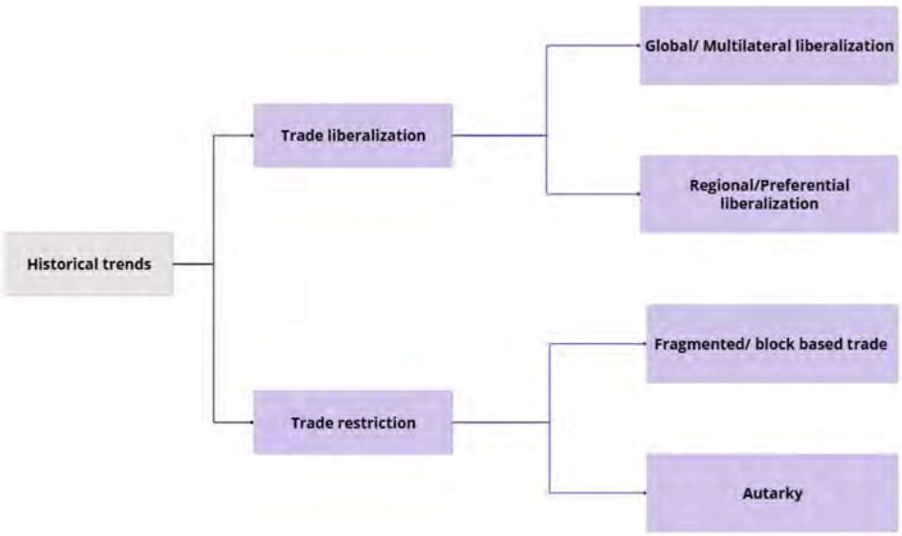

Figure 3. Relevant dimensions for "*trade*"

Following the trajectories and combining the dimensions we have 4 alternative combinations describing the scenario space for the "**trade**" macro-dimension:

- **High Trade Liberalization – Low Degree of Trade Asymmetries**. An open and relatively balanced global trading system where barriers are low and economic power is evenly distributed.
- **High Trade Liberalization – High Degree of Trade Asymmetries**. A highly open global market in which trade flows are dominated by a few powerful economies, leading to dependency patterns and uneven distribution of benefits.
- **Low Trade Liberalization – Low Degree of Trade Asymmetries**. A more protectionist but relatively balanced system where countries trade selectively within regional or bilateral arrangements without strong dominance by major powers.
- **Low Trade Liberalization – High Degree of Trade Asymmetries**. A fragmented and protectionist global economy characterized by limited trade flows and strong power imbalances, where dominant actors exert leverage through selective access and trade restrictions.

Moving to industry (Figure 3), we identify **market structure** (a) and the **degree of value chain geographical fragmentation** (b) as key dimensions. The former captures differences in market competition intensity and giving rise to two archetypal pathways. The first is characterised by concentrated and dominant industries, in which a limited number of large players exert substantial market power, shaping production structures, investment decisions, and trade outcomes. The second pathway corresponds to competitive and open industries, where a larger number of firms operate in more contestable markets, resulting in more dispersed production structures. We acknowledge that industries with different levels of market competitiveness can coexist within the same scenario. For this reason, to distinguish the different narrative pathways, we will consider how the key industries for decarbonization (e.g. semiconductors, battery technologies, green hydrogen) behave.

The **degree of value chain geographical fragmentation** captures how production processes are regionally organized in the creation of value, ranging from highly fragmented value chains, where intermediate inputs produced by other firms abroad are extensively used, to low-fragmented or more integrated value chains, characterized by shorter production chains and a more limited reliance on foreign intermediates.

This framing allows us to distinguish industry-specific organisational features exploiting key trade indicators. While highly fragmented production structures may give rise to global value chains under conditions of high trade openness, fragmentation itself reflects production organisation and input–output complexity rather than cross-border exchange per se. Conversely, low-fragmentation production structures may persist under both open and restricted trade regimes. We omit also in this case the dimension related to innovation and technology adoption which will be treated more generally as part of the enabling factors. In Figure 4, we highlight the archetypal

Funded by
the European Union

pathways obtained from the intersection of the two dimensions already discussed.

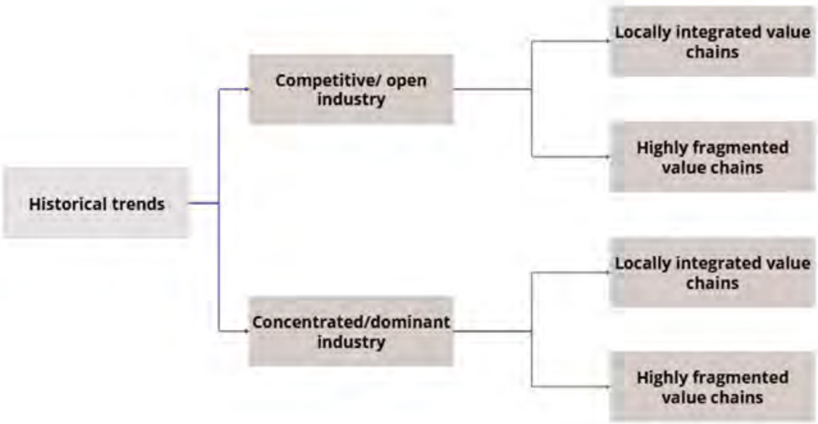

Figure 4. Relevant dimensions for "*industry*"

Following the trajectories and combining the dimensions we have 4 alternative combinations describing the scenario space for the "**industry**" macro-dimension:

1. **High Market Concentration – High Internationally Integrated Value Chains.** Large multinational firms drive coordinated global initiatives, enabling rapid implementation of new technologies and standardized practices, but outcomes may be vulnerable to geopolitical disruptions and corporate lock-in effects.
2. **High Market Concentration – Low Internationally Integrated Value Chains.** Dominant national players lead domestic strategies, allowing for strong coordination and strategic planning, but potentially limiting innovation and competition.
3. **Low Market Concentration – High Internationally Integrated Value Chains.** A diverse set of firms competes within global value chains, fostering innovation, cost reductions, and rapid diffusion of new practices and technologies across multiple sectors.
4. **Low Market Concentration – Low Internationally Integrated Value Chains.** Localized and fragmented markets support community-driven initiatives and regional experimentation, but scaling up innovations may be slower due to limited coordination and capital concentration.

When analysing the key dimensions for the environment, building on the workshop outcomes, it becomes clear that GHG emission levels represent a primary determinant of archetypal pathways. This is a first bifurcation (a) between high mitigation ambition, associated with low-emissions pathways, and low mitigation ambition, associated with persistently high emissions (Figure 5).

Mitigation ambition (a) is defined here in terms of aggregate and global outcomes, reflecting the extent to which climate objectives are effectively pursued at the system level. A second bifurcation relates to environmental dimensions beyond climate, which we emphasize under **environmental**

protection (b). These captures varying degrees of policymakers' commitment to environmental preservation, particularly with respect to land-use change pressures and outcomes, biodiversity, extraction and processing of critical raw materials, waste generation, and circular economy dynamics. These dimensions capture environmental impacts that are not directly reflected in GHG emissions and may evolve differently from climate mitigation trajectories. This framing allows the environment layer to capture broad contrasts in climate and non-climate environmental outcomes.

Environmental protection is treated here as an outcome-oriented dimension rather than as a set of specific regulatory instruments. Environmental regulations and mitigation policies are therefore not included explicitly, as they represent mechanisms through which shifts across archetypal pathways may occur. Different pathways may also reflect varying contributions across sectors and environmental domains, depending on the structure of production and consumption and the technologies deployed.

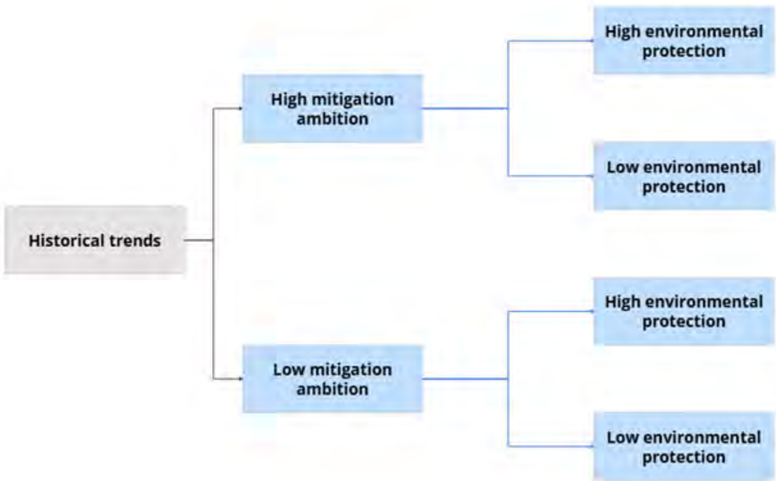

Figure 5. Relevant dimensions for the "*environment*"

Following the trajectories and combining the dimensions we have 4 alternative combinations describing the scenario space for the "**environment**" macro-dimension:

5. **High Climate Ambition – High Environmental Protection**. A sustainability-oriented future where strong climate mitigation and robust environmental safeguards enhance water efficiency, ecosystem resilience, and long-term resource security.
6. **High Climate Ambition – Low Environmental Protection**. A climate-focused but growth-driven pathway where mitigation limits warming, yet weak environmental regulation risks local ecosystem degradation and resource overuse.
7. **Low Climate Ambition – High Environmental Protection**. A climate-stressed future where limited mitigation increases impacts, but strong environmental governance and adaptation measures help buffer water and ecosystem pressures.
8. **Low Climate Ambition – Low Environmental Protection**. A high-risk trajectory marked

by severe climate impacts, weak environmental oversight, intensified resource exploitation, and growing water scarcity and conflicts.

When analysing the archetypal pathways that may emerge from socioeconomic drivers and enabling factors (Figure 6), a first key dimension is the **degree of technological and structural transformation** (a), which creates a primary bifurcation. One archetypal pathway reflects rapid and transformative technological progress, characterised by accelerated innovation, strong diffusion of advanced technologies, and deep restructuring of production systems. The other pathway represents low technological dynamism, where innovation proceeds slowly, adoption rates remain limited, and existing economic structures persist with minimal change.

Technological progress is here understood as generalized and pervading the entire economy. While general productivity trends are an important background driver of long-term economic growth, its focus is primarily on technological change relevant for climate and environmental transitions, including low-carbon technologies, resource-efficient production processes, and innovations that reduce environmental pressures. These changes may be partly endogenous within models, but their pace and effectiveness can differ across archetypal pathways through variations in learning dynamics, diffusion speeds, and policy or market incentives.

A second dimension is introduced through **socioeconomic and political enablers** (b), which determine whether the surrounding context is reinforcing or inhibiting. This dimension summarises a wide range of enabling conditions including institutional and governance capacity, political economy dynamics, cultural and social dynamics, education and human capital, economic development, natural resource endowments and financial enablers.
Favourable enablers create conditions that amplify technological progress and facilitate structural transformation. Conversely, weak governance, limited capacity, or misaligned incentives constrain progress, resulting in inhibited socioeconomic contexts.

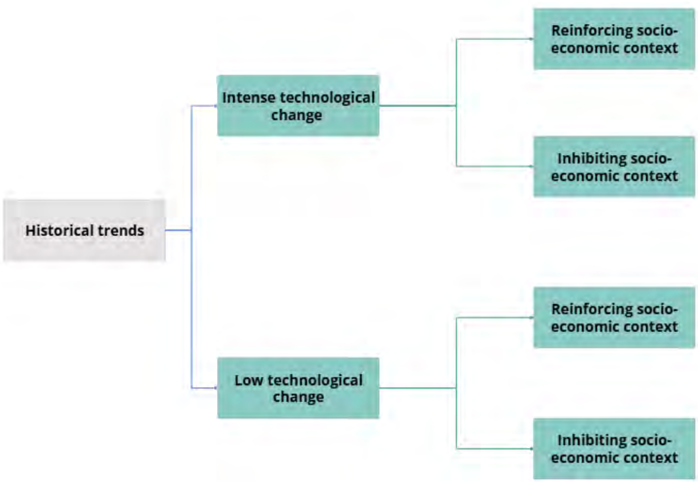

Figure 6. Relevant dimensions for "*enabling factors*"

Following the trajectories and combining the dimensions we have 4 alternative combinations describing the scenario space for "**enabling factors"** macro-dimension:

9. **High Technological Change – Reinforcing socio-economic context**. A dynamic transformation pathway where rapid innovation is supported by strong institutions, investment capacity, skills, and public acceptance, enabling large-scale and inclusive system transitions.
10. **High Technological Change – Inhibiting socio- economic context**. A technology-push trajectory in which breakthroughs occur quickly, but weak governance, limited finance, or social resistance constrain diffusion and equitable adoption.
11. **Low Technological Change – Reinforcing socio-economic context**. A coordination-driven pathway where strong policies, institutions, and societal support foster incremental improvements and behavioural change despite slower technological progress.
12. **Low Technological Change – Inhibiting socio- economic context**. A stagnation scenario marked by limited innovation and weak institutional or societal capacity, resulting in slow structural change and persistent systemic inefficiencies.

4.2 Examples of archetypal narratives

After having identified dimensions shaping narratives for the futures, the next task is to follow some of the resulting archetypal pathways and enrich the related narratives by coherently building their underlying stories across different analytical layers used to structure narratives (from the global to the sectoral level) and ensure that scenarios cover multiple domains (e.g., political, economic, technological, environmental, social). The common analytical layers we will rely on in this section are Global Trade and its governance (Trade and GVCs), Industry and production structures (Production & Costs and Industrial Organisation), Climate ambition and environmental protection (Environmental Outcomes and Climate & Environmental policy), Technological and socio-economic enablers (Governance and Technology & Innovation). These layers are used to describe three possible archetypal narratives:

13. **Coordinated Globalization**. This narrative follows the path of high trade openness and symmetry in international trade among countries and high climate ambition and environmental protection. Key industries for decarbonization are dominant at the global level and they act as "global champions".
14. **Regionalized Fragmentation**. This narrative is characterized by a medium level of trade openness and increasing asymmetries. However, climate ambition and environmental protection are still high as in the previous narrative. Here, key low carbon technologies are dominant at the regional scale, and they are called "regional champions".
15. **Fragmented Isolation**. This narrative portrays a trade openness close to zero and high asymmetries. Finally, climate ambition and environmental protection are at low levels. In this case key low carbon technologies may still be dominant at the national scale, and they are called "national champions". In a low climate ambition scenario, this is the result of

strategic industrial, economic, or geopolitical priorities, not environmental goals.

4.2.1 Coordinated Globalization

By the mid-21st century the global economy has entered a phase of **deeply coordinated globalization**, shaped by an **urgent and widely** shared **commitment to climate stability and environmental protection**. Rather than retreating from global trade, governments, firms, and consumers have restructured globalization itself to align with sustainability goals.

Global Trade and its governance

International trade remains extensive, but it is governed by **robust multilateral frameworks** that embed **climate and environmental standards** at their core. Trade agreements now routinely include binding commitments on emissions reduction, biodiversity protection, and resource efficiency.

Global value chains are **highly interconnected** and technologically sophisticated, optimized not only for cost and efficiency but also for low carbon intensity and resilience. Digital traceability systems allow real-time monitoring of emissions (MRV), resource use, and labour conditions across entire supply networks. This transparency has become a prerequisite for market access.

Industry and production structures

Production is **internationally distributed** according to comparative advantages in clean energy, skills, and ecological capacity, rather than solely on labour costs. Some stages of production are regionally clustered to **reduce transport emissions and maximise synergies**, but these clusters remain tightly integrated into global networks rather than nationally self-contained. In general, **upstream** (e.g. semiconductors, rare materials) and **low carbon capital intensive industries** (e.g. green hydrogen, CCS, batteries) become **more dominant**, while **downstream activities** (e.g. components for renewables, energy efficiency, low-carbon agri-food) **and services** (e.g. MRV, ESG consultancy) remain highly **competitive**, with climate policy accelerating both innovation and concentration.

Climate ambition and environmental protection

Carbon pricing mechanisms are **internationally aligned**, and **carbon border adjustments** ensure fair competition while discouraging environmental dumping.

Environmental protection is no longer treated as a constraint on growth but as a foundation for long-term economic stability. **Deforestation, ecosystem degradation, and pollution** have **declined** significantly due to strict enforcement, market incentives, and global cooperation.

Technological and socio-economic enablers

Rapid diffusion of green technologies underpins this system. High levels of R&D spending, combined with continuous efficiency improvements and the widespread adoption of Best Available Technologies (BAT), drive innovation across sectors. Open innovation platforms, cross-border research alliances, and climate-focused intellectual property sharing accelerate the **deployment of renewable energy**, **circular manufacturing**, and nature-positive solutions. Heavy industries, once major emitters, have been transformed through **electrification**, **green**

Funded by
the European Union

hydrogen, and **closed-loop material systems**. Firms compete globally on sustainability performance as much as on price or quality. Environmental excellence has become a source of comparative advantage and brand value.

Inclusive economic systems, **strong institutions**, **open and integrated markets**, and **high social trust in science and governance** enable the system to strongly coordinates in different fields. These conditions allow globalization and ambitious climate action to reinforce each other, resulting in low challenges to mitigation and relatively low challenges to adaptation.

4.2.2 Regionalized Fragmentation

By the mid-21st century, the global system has reorganized around a **limited number of large, relatively cohesive regional blocs**. While global multilateralism remains weaker than in earlier decades, **cooperation within blocs deepens** significantly, driven by shared economic interests, regulatory alignment, and common climate and environmental objectives. **Trade flows** are **dense within blocs** but more **selective** and regulated **across** them.

Global Trade and its governance

Economic integration within blocs supports relatively **efficient regional value chains**. Firms restructure production to comply with shared environmental and labour standards, leading to shorter, more transparent supply chains. While **cross-bloc trade persists**, particularly for **critical raw materials** and **strategic technologies**, it is increasingly governed by climate-related criteria, environmental standards, and sustainability certification.

Industry and production structures

Strong environmental regulation drives **rapid deployment of renewable energy**, **electrification**, **energy efficiency**, and **circular economy** practices. **Regional industrial strategies** support **clean manufacturing and infrastructure**, while public and private investment flows are aligned with climate and biodiversity goals. **Fossil fuel use declines** steadily, though at **different speeds across blocs** depending on resource endowments and political priorities.

Upstream (e.g. clean energy, renewables)**, high-tech** (e.g. semiconductors, battery technologies)**, and decarbonization-enabling industries dominate** (e.g. recycled metals, bio-based plastics, sustainable chemicals, catalysts), driven by climate ambition, regulation, and bloc-level coordination. Instead, **downstream** (e.g. electronics, appliances, vehicles), **consumer-focused** (e.g. agriculture and agri-food, sustainable construction materials, green buildings), **and service sectors** (e.g. finance, logistics, consulting, IT services), remain **competitive**, with strong regional markets but lower influence on the overall economic and environmental trajectory.

Climate ambition and environmental protection

Climate ambition is **high across all major blocs**. Governments view climate action as a strategic priority, both to reduce climate risks and to secure leadership in clean technologies. Regional climate frameworks go beyond previous global agreements, setting **binding emissions targets**, **coordinated carbon pricing mechanisms**, and **common regulatory standards for energy, industry, and transport**. Environmental protection is embedded in economic policy rather than

Funded by
the European Union

treated as a constraint.

Environmental protection extends beyond climate mitigation. Blocs adopt **robust biodiversity conservation policies, land-use planning, and pollution controls**, supported by harmonized enforcement mechanisms. Environmental monitoring and MRV systems are well-funded and transparent, increasing accountability and policy credibility. Cross-border environmental spillovers within blocks are addressed cooperatively, reducing regulatory competition.

Technological and socio-economic enablers

Socially, the transition is managed through coordinated labour-market policies, social protection, and regional funding mechanisms that support affected workers and regions. Inequality within blocs is moderated, although **disparities between blocs** persist due to uneven access to resources, technology, and finance. **Migration** is managed primarily **within blocks**, supporting labour mobility while maintaining political stability.

While the bloc-based system limits the scale of global coordination, it proves sufficiently robust to sustain high climate ambition and environmental protection. Competition between blocs increasingly takes the form of "green leadership," with technological innovation, regulatory quality, and environmental performance becoming key dimensions of geopolitical influence.

4.2.3 Fragmented Isolation

By the mid-21st century, the global economy has settled into a pattern of fragmentation and guarded self-interest. A succession of geopolitical shocks, trade disputes, and domestic political pressures has pushed governments toward protectionism as the dominant economic doctrine. National resilience, narrowly defined in terms of short-term supply security and political stability, has replaced efficiency and global cooperation as the guiding principle of policymaking.

Global Trade and its governance

International trade volumes have stagnated in the recent decade. **Tariffs, local content requirements, and regulatory barriers** are now standard policy tools used widely by many, justified as necessary to protect domestic industries and employment. Multilateral trade institutions have weakened, their rules increasingly ignored or selectively applied. In this environment, **global value chains have unravelled**. Firms that once relied on complex, cross-border production networks have either **reshored production** or **reorganized supply chains within small, politically aligned regional blocs**. The result is a patchwork of semi-autarkic production systems that are more redundant, more costly, and less innovative than their predecessors.

Industry and production structures

Economic inefficiency is widespread. **Production costs have risen** as firms duplicate facilities and rely on smaller domestic markets. **Consumer prices are higher**, particularly for manufactured goods and technologies that once benefited from global specialization. **Productivity growth** has **slowed**, as reduced competition and limited knowledge exchange weaken incentives for innovation. Small and developing economies, unable to sustain full domestic production ecosystems, face chronic shortages, lower investment, and declining export revenues.

Industries that dominate tend to be **resource-intensive, protected, or strategically critical for domestic survival**, rather than technologically innovative. Dominance is often **national or regional**, not global. Industries that remain competitive tend to be **smaller, flexible, or service-oriented**, but their growth is limited by fragmented markets and protectionism. They include, for instance, consumer goods and services (e.g. electronics, appliances, food processing), downstream low-tech manufacturing (e.g. furniture, textiles, consumer plastics), and niche technological sectors (e.g. semiconductors, industrial automation).

Climate ambition and environmental protection

Climate policy has suffered in this **inward-looking world**. Governments frame climate action as a constraint on competitiveness rather than a shared global challenge. International climate negotiations persist but produce minimal commitments, largely non-binding and poorly enforced. National climate targets, where they exist, prioritize symbolic gestures over structural transformation. **Fossil fuels remain central** to energy systems, justified by **energy security concerns** and the desire to shield domestic industries from transition costs.

Environmental protection more broadly has **weakened**. Regulatory standards are diluted in the name of competitiveness and domestic industrial revival. Environmental impact assessments are streamlined or bypassed, and enforcement capacity is uneven. **Resource extraction expands**, particularly mining, agriculture, and fossil fuel production, as governments seek to maximize domestic output. **Ecosystem degradation** accelerates, with **deforestation, water pollution, and biodiversity loss** treated as acceptable trade-offs for economic and political stability.

Technological and socio-economic enablers

Low climate ambition is reinforced by the breakdown of integrated GVCs. **Clean energy technologies**, once diffused rapidly through global supply chains, are now **expensive**, unevenly available, and often subject to export controls. Many countries lack access to critical components, expertise, or financing, **slowing deployment of renewable energy**, **electrification**, and **energy efficiency measures**. Rather than coordinating decarbonization pathways, countries pursue isolated and often contradictory strategies.

Social and environmental inequalities deepen. Wealthier countries can partially shield themselves from the worst impacts through subsidies and infrastructure investment, while poorer countries bear disproportionate environmental damage and economic volatility. Climate impacts, such as heatwaves, floods, and crop failures, intensify, but responses remain reactive and national rather than coordinated and preventive.

Figure 7 below compares the three archetypal narratives according to the four macro dimensions and six analytical layers expanding the scenario dimensions: trade and Global Value Chains integration (for trade), industrial organization, and production & costs (for industry), climate policies and environmental protection (for climate), governance and technology & innovation (for enabling factors).

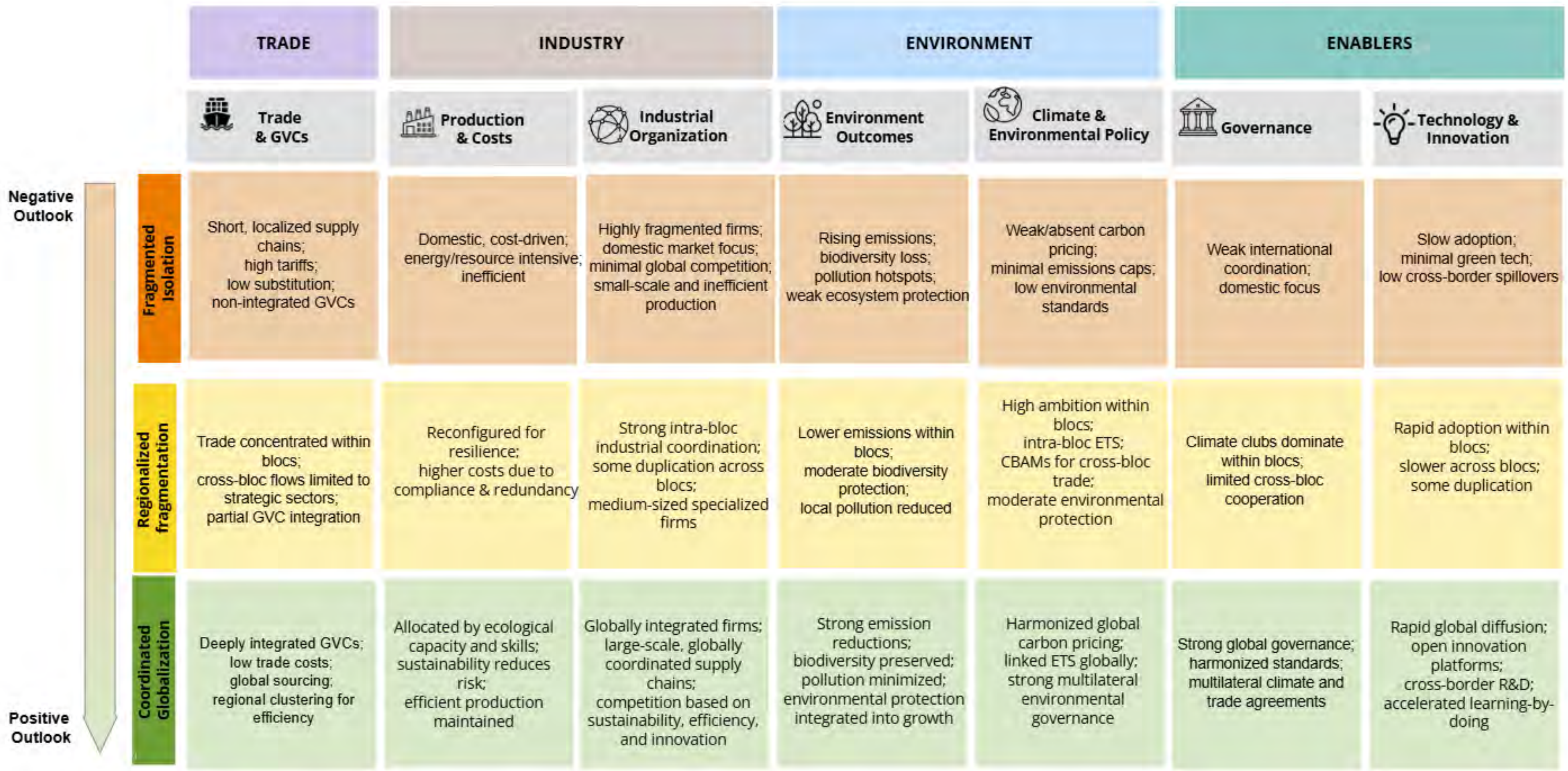

Figure 7: Comparison of the three archetypal narratives across layers and macro- dimensions

Together, the figure emphasizes how the degree of trade integration and governance effectiveness critically influence technological progress, industrial efficiency, and environmental outcomes, highlighting that fragmented or partially integrated worlds face greater challenges in managing the dual goals of economic resilience and climate sustainability.

4.3 Towards the operationalization of the three archetypes

One of the central challenges in scenario framework design is ensuring coherence between **narratives** (intrinsically qualitative) and **quantitative model outputs**. Storylines describe how the world evolves, often involving elements such as governance quality, social cohesion, or international cooperation, while models translate assumptions into measurable trajectories and projections of variables such as productivity growth rates, trade elasticities, capital accumulation, or energy intensity. Without a structured bridge between the two, scenario exercises risk producing narratives that are analytically rich but numerically unsupported, or model results that are technically precise but conceptually disconnected. **Analytical layers** provide the bridge organizing the system into distinct but interacting analytical levels that clarify where qualitative assumptions operate and how they should be translated into model parameters.

Building on the three archetypes previously introduced, we integrated them with a set of modelling levers that could be applied if these archetypes were used in the modelling exercises planned for WP4. We acknowledge that the choice of the levers is strictly interconnected with the features of the models, here we will refer primarily to variables, relationships and parameters that are mostly common in CGE modelling without relying on modelling improvements of WP3.

4.3.1 Coordinated Globalization

Figure 8 summarizes how the **Coordinated Globalization** scenario is translated from a qualitative narrative into concrete modelling assumptions across key system layers, including trade and global value chains, production and costs, industrial organization, climate and environmental policy, environmental outcomes, governance, and technology and innovation. For each layer, the table specifies parameter choices, functional forms, or institutional settings (e.g. low trade costs, high substitution elasticities, endogenous technological change, and harmonized global standards) that collectively enable strong international integration and coordinated climate action. The accompanying comments on the operationalization clarify (i) how these assumptions shape model behaviour (e.g. sustaining deep global value chains, accelerating the diffusion of low-carbon technologies, and reallocating capital and labour toward cleaner sectors), and (ii) at a what extent elements within the dimensions can be translated into model features.

Funded by
the European Union

	Trade & GVCs	Production & Costs	Industrial Organization	Climate & Environmental Policy	Environment Outcomes	Governance	Technology & Innovation	
Coordinated Globalization	Low global trade costs: high Armington substitution elasticities across all regions. Highly integrated global value chains with strong cross-border trade in intermediates. Moderate regional clustering introduced via lower transport emissions coefficients rather than trade barriers.	Efficient global reallocation of capital and labor toward low-carbon sectors. Lower long-run production costs due to scale economies and technology learning.	Higher TFP growth in low-emission and circular sectors. Penalize high-emission sectors via higher effective input costs. High elasticities across goods and varieties. Low scope for price markups. High substitution elasticities for imported intermediates. Low home bias in IO nests.	Harmonized global carbon price or globally linked ETS. Binding global emissions constraint consistent with ambitious temperature targets. Strong global constraints on land use change, biodiversity loss, and pollution. Limited use of CBAMs, primarily as enforcement tools for non compliance.	Tight production coefficients on pollution, land-use change, and resource exploitation. Shadow prices on natural capital. Emission and pollution caps. Adjust emissions coefficients, pollution intensities, and resource-use parameters. Improvements in closed-loop and circular production	Strong multilateral institutions with enforcement capacity. Harmonized climate, trade, and environmental standards globally. Limited use of CBAMs, mainly as compliance safeguards.	Sectoral factor productivity and technology coefficients adjusted according to renewable energy potential, skills, and resource efficiency. Strong endogenous technological change driven by learning-by-doing and R&D spillovers. Rapid diffusion of low-carbon technologies across all regions. High elasticities of substitution in energy and material nests.	**Model Closures:** Efficient global reallocation of capital and labor.
Operationalized narrative elements	It maintains deep global integration of goods and intermediates. It keeps GVCs optimized for cost and sustainability, with some regional clustering to reduce transport emissions	It mimics production and cost dynamics driven by high international mobility of capital and labor, enabling efficient global reallocation toward low-carbon sectors. It integrates economies of scale, global learning-by-doing and strong technology spillovers to reduce unit production costs over time.	It reflects: 1. large, globally integrated firms operating across borders. 2. Strong economies of scale and high sectoral productivity growth. 3. Competition based on efficiency, innovation, and environmental performance.	It reflects global climate club coordination. It ensures fair competition while incentivizing emission reductions in exporters.	It ensures biodiversity, reduced ecosystem degradation, and low local pollution, consistent with ambitious climate. It leads to lower global emissions, reduced deforestation, and improved ecosystem integrity	It considers trong global governance; harmonized standards; multilateral climate and trade agreements.	It guides production toward regions with comparative advantage in sustainable production. It models fast adoption of renewables, green hydrogen, circular manufacturing, and nature-positive solutions.	

Figure 8: Operationalization of the Coordinated Globalization narrative across layers.

4.3.2 Regionalized Fragmentation

Figure 9 operationalizes a **Regionalized Fragmentation** scenario by translating a qualitative narrative of geopolitical fragmentation and bloc-based coordination into explicit modelling assumptions. It details how limited cross-bloc integration, differentiated climate and environmental policies, and regionally anchored technological and industrial strategies are implemented across key model dimensions, including trade and global value chains, climate policy, technology and innovation, production structures, industrial organization, environmental outcomes, and governance. By doing so, the table clarifies the channels through which regionalization and partial economic decoupling influence production patterns, technology diffusion, and environmental performance, making the underlying narrative analytically tractable within a formal modelling framework.

	Trade & GVCs	Production & Costs	Industrial Organization	Climate & Environmental Policy	Environment Outcomes	Governance	Technology & Innovation	
Regionalized Fragmentation	Low trade costs and high Armington elasticities within blocs; higher trade costs across blocs. Partial GVC integration: strong intra-bloc specialization; restricted cross-bloc intermediate trade. Lower cross-bloc trade costs for clean energy tech, critical minerals, environmental services Sector-specific trade cost wedges or efficiency penalties for non-compliant exporters	Reallocation of production toward low-carbon sectors within blocs. Higher production costs due to regulatory compliance, redundancy, and shorter GVCs. Moderate efficiency losses offset by learning effects and scale within blocs.	Firms integrated within blocs. Sectoral productivity higher due to intra-bloc specialization. Medium-scale capital and technology adoption. Partial trade in strategic sectors.	Binding emissions caps or high carbon prices within blocs, consistent with net-zero targets. Linked ETS or harmonized carbon prices intra-bloc; differentiated carbon prices across blocs. Carbon border adjustment mechanisms (CBAMs) applied to imports from non-aligned blocs. Binding constraints on land-use change and pollution within blocs.	Declining emissions and pollution within blocs. Reduced leakage due to CBAMs, but incomplete global emissions reduction. Improved local environmental quality and biodiversity protection in regulated regions.	Climate clubs dominate governance structures within blocs. Strong coordination on standards and pricing intra-bloc; limited cooperation across blocs. Trade–climate linkage enforced via CBAMs and regulatory conditionality.	Strong endogenous substitution toward low-carbon energy and materials within blocs. Accelerated capital turnover toward clean technologies. Strong intra-bloc technology spillovers; weaker cross-bloc diffusion.	**Model Closures:** Full employment with reallocation primarily within blocs.
Operationalized narrative elements	It reflects geopolitical tensions, regulatory divergence, and strategic autonomy concerns. It maintains cohesion of regional value chains. It mimics certification, due diligence, sustainability rules. It reflects managed cooperation and mutual dependence in climate-critical sectors.	It captures costs of regulatory compliance, supply-chain transparency, redundancy	It captures regionally integrated production systems, with firms exploiting economies of scale and specialization within blocs, facing strong intra-bloc competition.	It ensures emissions decline along ambitious pathways. Marginal abatement cost equalization within bloc. It prevents leakage and protects domestic climate policies	It captures limits on resource exploitation and local pollution	It considers harmonized climate or trade clubs where domestic/regional policy focus dominates.	It describes strong within bloc spillovers and weaker cross-bloc diffusion	

Figure 9: Operationalization of the Regionalized Fragmentation narrative across layers

4.3.3 Fragmented Isolation

Figure 10 presents the operationalization of a **Fragmented Isolation** scenario, translating a qualitative narrative of widespread protectionism, inward-looking economic strategies, and weak international cooperation into concrete modelling assumptions. It specifies how high bilateral trade barriers, minimal climate ambition, limited technological spillovers, and domestically focused production systems are implemented across core model dimensions, including trade and global value chains, climate and environmental policy, technology and innovation, production and cost structures, industrial organization, environmental outcomes, and governance. By making these assumptions explicit, the table clarifies the channels through which isolationist policies and institutional fragmentation shape economic performance, technological change, and environmental degradation within the modelling exercise.

	Trade & GVCs	Production & Costs	Industrial Organization	Climate & Environmental Policy	Environment Outcomes	Governance	Technology & Innovation	
Fragmented Isolation	High bilateral tariffs and iceberg trade costs across all regions. Low Armington substitution elasticities between domestic and imported goods and among import sources. Strong home bias in intermediate input sourcing; limited cross-border trade in intermediates.	Energy- and resource-intensive production structures. Higher unit production costs due to loss of scale economies and inefficient input combinations. Capital accumulation biased toward incumbent, fossil-intensive technologies.	Firms primarily domestic. Armington substitution mostly domestic vs imported. Low technology spillovers.	No binding emissions caps; carbon prices set to zero or negligible levels. Weak environmental regulation: high emissions and pollution coefficients in production. No binding constraints on land-use change, deforestation, or resource extraction.	Rising global emissions and pollution levels. Accelerated biodiversity loss and ecosystem degradation. Increasing exposure to climate damages (if represented endogenously).	Weak multilateral institutions and limited international coordination. Policies determined domestically with little harmonization across regions. Absence of climate clubs, CBAMs, or shared standards	Low autonomous energy efficiency improvement (AEEI). Limited substitution possibilities between fossil and low-carbon energy technologies. Minimal international technology spillovers; weak learning-by-doing effects.	**Model Closures:** Full employment of factors with domestic reallocation only.
Operationalized narrative elements	It reflects protectionism, import quotas, and reduced international market access. It captures non-integrated, fragmented GVCs and limited cross-border coordination.	Energy- and resource-intensive production dominates. It depicts ocalized supply chains reduce economies of scale. Inefficient practices persist.	Firms operate mainly within national markets. Very limited multinational activity or cross-border production networks. Markets are segmented by borders, not integrated internationally.	Low climate ambition. marginal abatement cost constraints minimal. Environmental standards poorly enforced or voluntary.	Weak climate and environmental governance prevents mitigation of environmental risks.	No harmonized climate or trade clubs. Domestic policy focus dominates.	Innovation focused on cost efficiency rather than sustainability. Green tech adoption limited.	

Figure 10: Operationalization of the Fragmented Isolation narrative across layers

Funded by the European Union

The three tables collectively illustrate distinct approaches to operationalizing complex futures narratives within a modelling framework, showcasing how qualitative storylines are translated into explicit assumptions, parameter settings, and model structures. Each table demonstrates varying degrees of granularity and structural choices that shape the scope and dynamics of the model outcomes. In the **Coordinated Globalization** operationalization, the process emphasizes strong internal consistency and alignment across model domains, with assumptions calibrated to reflect high integration and policy harmonization. This involves setting parameters, such as low trade costs, high substitution elasticities, endogenous technological change, and effective governance mechanisms, which together create a tightly coupled system that reinforces the narrative's optimistic vision through model closures and functional forms.

The **Regionalized Fragmentation** table reflects a more complex operationalization challenge by introducing segmentation and differentiated assumptions across blocs. Here, the operational process involves balancing internal bloc cohesion with cross-bloc frictions, requiring nuanced parameter adjustments, such as intra-bloc high substitution elasticities but lower cross-bloc spillovers, differentiated carbon prices, and regionalized supply chains. This adds layers of complexity in the model's structure, necessitating careful calibration to maintain internal bloc dynamics while realistically limiting global integration. The process also involves explicitly modelling enforcement mechanisms like carbon border adjustment mechanisms (CBAMs) to capture partial cooperation and regulatory conditionality, which highlights the importance of embedding governance features in operational terms.

In contrast, the **Fragmented Isolation** scenario's operationalization is characterized by assumptions that include fragmentation and inefficiency into the model. The process here involves setting restrictive parameter values, such as high bilateral tariffs, low elasticities, weak technology spillovers, and limited climate policies, that constrain the model's ability to endogenously generate cooperation or efficiency gains. This requires deliberate choices to represent domestic market orientation and institutional weakness, often by imposing closures that limit factor reallocation and exclude international coordination mechanisms. Through this approach, the operationalization process foregrounds the structural barriers and path dependencies associated with fragmentation, embedding pessimistic outcomes directly into the model framework.

Overall, these operationalization processes reveal how the translation of futures narratives into model assumptions is not merely a mechanical exercise but a deliberate design involving trade-offs between realism, tractability, and analytical clarity. The variation in parameter settings, model closures, and institutional representations across the three scenarios reflects differing priorities in capturing global integration versus segmentation, efficiency versus resilience, and cooperation versus isolation. Understanding these operational choices is essential for interpreting model outputs critically and for designing scenario sets that meaningfully explore alternative futures.

Funded by
the European Union

5 Reference narrative and scenario

The three archetypal narratives outlined above offer complementary perspectives on possible development pathways. Together, they frame the range of alternative futures and clarify their underlying assumptions. Building on this foundation, the next section introduces the reference scenario, which provides a consistent baseline against which these narrative trajectories can be compared and assessed.

To ensure coherence across model results while maintaining a workable experimental design, ENTICE adopts a single reference narrative/scenario as the backbone for all subsequent quantitative and qualitative assessments. A unified reference scenario provides a neutral benchmark against which to evaluate the impacts of the trade, climate, and industrial policy shocks we aim to study, and serves as a narrative anchor that links qualitative storylines with quantitative modelling choices. The reference scenario should represent the world as it stands today, remain consistent with historical socioeconomic data up to 2024 (prior to April 2nd, 2025[3]), and assume a continuation of recent historical trends.

After considering various advantages and limitations, ENTICE anchors its reference scenario to the Shared Socioeconomic Pathways (SSPs), which continue to be the most widely used and systematically developed set of global narratives and long-term socioeconomic projections. Accordingly, ENTICE adopts an updated version of SSP2 ("Middle of the Road") as the backbone of the reference scenario.

5.1 Core drivers

The analysis of short-, medium-, and long-term implications of a complex policy landscape, spanning trade, industry and climate measures, requires to first define the reference pathways for main socioeconomic variables, mainly GDP and population. The **latest SSP projections** (version 3.2[4]) of GDP are characterised by historical trends up to 2022, short-term IMF-OECD forecasts up to 2026 and long-term forecasts from 2027 up to the end of the century.

From a quick comparison of SSP historical trend of GDP with more recent updates of the World Economic Outlook (IMF, 2025), it seems preferrable to adjust SSPs to recent growth shifts. Most models will have 2023 as base year which was not historical in current SSP release and shows a relevant gap from the historical data (Figure 11).

[3] In 2025 President Donald Trump repeatedly referred to April 2, 2025 as "Liberation Day", using the label to frame a planned announcement and implementation of broad reciprocal tariff measures intended to reshape U.S. trade policy and reduce trade imbalances.
[4] IIASA SSP database v3.2, May 2025 https://ssp.apps.ece.iiasa.ac.at/documentation/basic-drivers

Funded by
the European Union

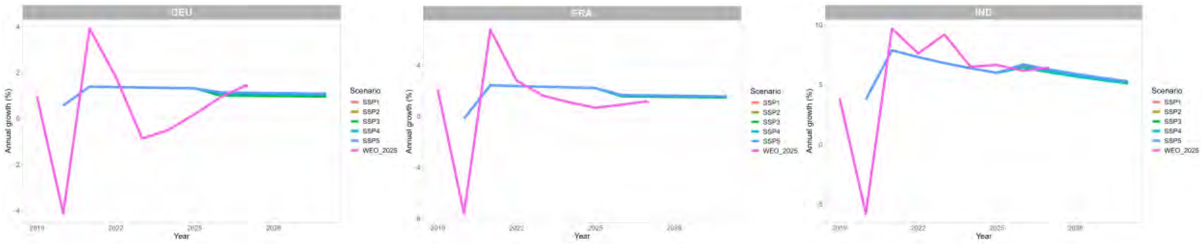

Figure 11. SSP2 vs. World Economic Outlook (October 2026)

Therefore, the plan in ENTICE project activities is to update the historical SSP2 trends up to 2025 using the World Economic Outlook (IMF) for GDP and the World Development Indicators (World Bank) for population and other socioeconomic variables. The **WEO database** provides short-term forecasts (up to 2030) for GDP and key economic indicators. However, because we aim to assess the impacts of policies taking effect from 2025 onward, we are concerned that the WEO projections may already incorporate expectations about these policy impacts, particularly those related to US trade tariffs. From 2025 onward, we therefore apply SSP2 growth rates for the main socioeconomic variables to determine the future evolution of our reference scenario. The transition between the historical and the SSP growth rates can be tuned using statistical methods (e.g. multi-year smoothing or rolling averages).

5.2 Other drivers

The ENTICE project aims to analyse a wide set of dimensions related to the trade–industry–environment nexus, as outlined in Section 2. Therefore, the reference scenario must specify a plausible range of trajectories for non-socioeconomic variables to ensure internal coherence of the overall framework. The guiding principle for this task is to draw on the satellite SSP literature to define likely evolution of resource availability, including critical raw materials, as well as environmental pressures and technological pathways. Alternatively, other authoritative sources, such as the IEA World Energy Outlook 2025 and the OECD Environmental Outlook 2025, should be considered to fill in any missing dimensions. For emerging or newly covered topics, past trend extrapolation may also be used, preferably expressed in terms of intensity indicators.

5.2.1 International Energy Prices

International energy prices in the ENTICE reference scenario could be based on the latest World Energy Outlook (WEO) (IEA, 2025). The IEA scenarios have several advantages: they are authoritative in their field, freely accessible, and regularly updated.

The **WEO2025** details three scenarios:

- A Current Policies Scenario (CPS), which assumes that energy and climate policies are those currently adopted in legislation and regulation.
- A Stated Policies Scenario (STEPS), which extends the CPS to policies formally announced

but not yet adopted, including those outlined in official documents.

- A Net Zero Emissions scenario (NZE), which represents a global pathway consistent with limiting global warming to 1.5 °C.

Under the CPS, the emissions pathway aligns with nearly 3°C of warming by 2100, while the lower emissions projected in the STEPS limit warming to about 2.5°C. The assumptions used in the CPS scenario are consistent with our reference scenario that considers currently implemented policies on top of an SSP2 scenario. Figure 12 presents the percentage change of international energy prices in the CPs scenario.

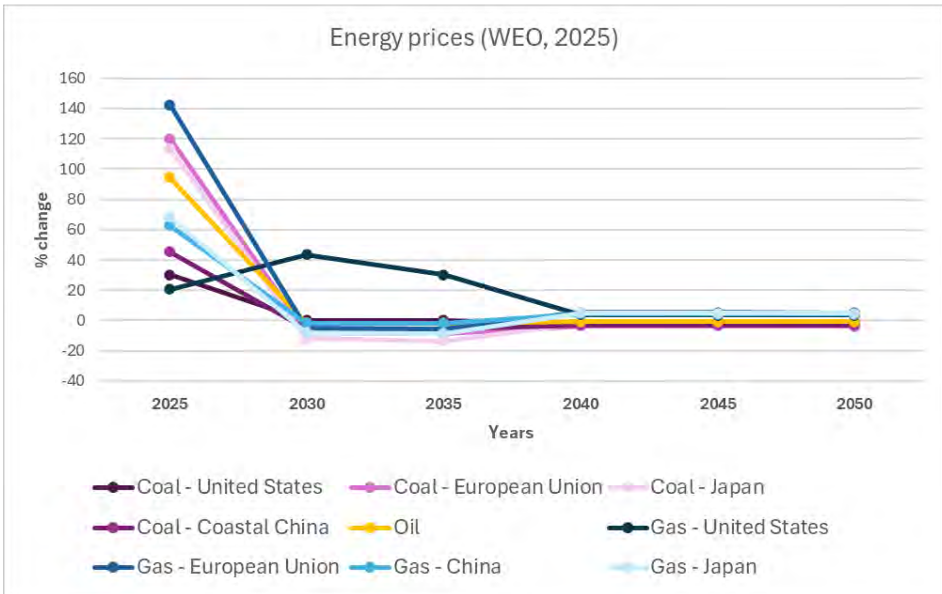

Figure 12. Percentage change of energy prices, our elaboration (IEA, 2025)

To **extend the trend after 2050**, we have two options: (i) Assume that energy prices continue to rise, extrapolating the growth rate observed over the 2035–2050; (ii) Assume that energy prices may stabilise, remaining constant at their 2050 level thereafter.

Alternative projections are available in the **NAVIGATE project** (van Heerden et al., 2025). In this project they adopt as a reference scenario a 'middle-of-the-road' socio-economic pathway (SSP2) combined with the current implementation of national policies (up to 2023), therefore very similar to the set of mitigation policies to be considered in ENTICE reference scenario. Figure 13 shows the percentage change in energy prices (coal, oil, and gas) across the different models included in the exercise. The results display a wide range of variation, which differs substantially from the projections reported in WEO2025.

Funded by
the European Union

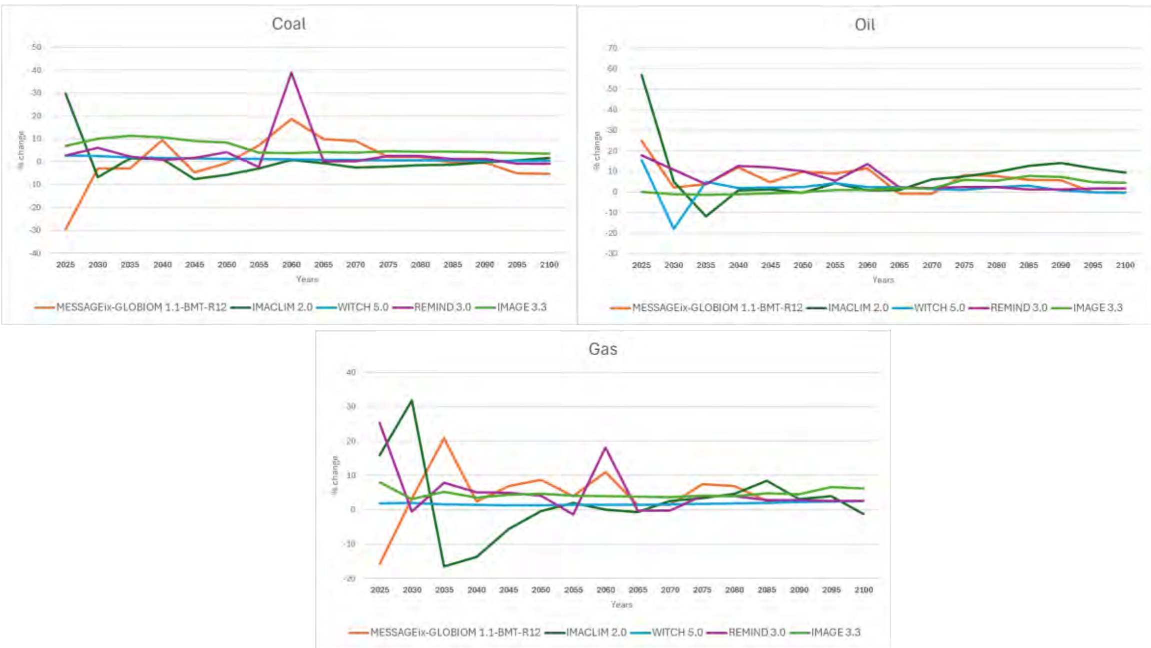

Figure 13. Percentage change of energy prices, NAVIGATE project (van Heerden et al., 2025)

5.2.2 Prices of key extractive materials or stock evolution

Beyond energy, ENTICE modelling studies need internally consistent assumptions for prices and/or availability of key extractive materials that matter for industrial production and the low-carbon transition (e.g. iron ore, coking coal, aluminium/bauxite, copper, nickel, cobalt, lithium, graphite, rare earth elements, and selected industrial minerals). These inputs influence competitiveness, trade patterns, and the feasibility and cost of decarbonisation options (electrification, batteries, renewables, grids, hydrogen).

A pragmatic approach is to anchor international price trajectories to a small number of authoritative, regularly updated global sources and then translate them into model-specific inputs (sectoral intermediate input prices, resource rents, or supply curves). As a default, we propose using the **World Bank Commodity Markets Outlook**[5] for bulk metals and minerals (medium-term projections and consistent historical series), complemented by the **IMF Primary Commodity Price data**[6] for historical calibration and by specialised critical-minerals outlooks (e.g. IEA critical minerals reports and datasets[7]) for transition-relevant materials where standard price forecasts are limited.

Because mineral price projections are highly uncertain and sensitive to technology, policy, and

[5] https://www.worldbank.org/en/research/commodity-markets/price-forecasts
[6] https://www.imf.org/en/research/commodity-prices
[7] https://www.iea.org/data-and-statistics/data-product/critical-minerals-dataset

Funded by the European Union

geopolitics, the reference scenario should not attempt to predict granular long-run price levels. Recent literature (Lundaev e al., 2023) highlights that, for several materials critical to the energy transition, **long-term availability** may become a binding constraint as demand increases, with potential implications for sustained price pressures and supply risks (see e.g. comprehensive reviews of critical materials for the energy transition). Instead, the reference scenario should provide: (i) a central path consistent with the CPS/SSP2 narrative (no major new constraints or breakthroughs beyond current policy and investment trends), and (ii) simple uncertainty ranges that can be activated as sensitivity tests in WP4 (for example, ±20-40% around the central path by mid-century for selected transition minerals, and wider ranges for lithium and rare earths where historical volatility and demand uncertainty are particularly high).

Operationally, models may represent extractive materials either through exogenous international price paths or through explicit resource-scarcity mechanisms (Fragkos et al., 2025). In price-taking frameworks, international prices (in real USD) are imposed for a limited set of primary commodities, with regional wedges reflecting trade and transport margins.

Stocks and resource availability can be described using standard indicators: proven reserves and resources, reserve-to-production ratios, and technically recoverable resources by region. USGS Mineral Commodity Summaries[8] provides consistent reserve estimates for many minerals; the IEA provides complementary information on project pipelines, refining capacity, and mid-stream bottlenecks relevant for critical minerals. Where data gaps remain, a transparent fallback is to extrapolate production trends and assume stable real unit extraction costs in the long run, documenting the assumptions explicitly so they can be revised as better information becomes available.

5.2.3 Key technology cost evolution

The WEO 2025 (IEA, 2025) is a valid source also for the evolution of technology cost. These assumptions offer a clear advantage in terms of internal consistency with energy price trajectories, which are of course an important factor in the evolution of technology costs.

The IEA provides technology cost assumptions covering two main areas:

- **Power generation technologies**: a comprehensive dataset reporting, for each scenario and each region over the period 2024-2050, the investment costs of power plants for coal (four technologies), natural gas (four technologies), nuclear, fossil fuel technologies equipped with CCS (four technologies), and renewable energy (thirteen technologies).
- **Other key technologies**: cost assumptions for selected technologies, including iron-based steel production, passenger cars (hybrid and battery electric), hydrogen

[8] https://www.usgs.gov/centers/national-minerals-information-center/mineral-commodity-summaries

Funded by the European Union

electrolysers, fuel-cell trucks, and utility-scale stationary battery storage.

Another recent publication (Vatankhah Ghadim et al., 2025) describes a new harmonized database of cost projections for clean energy technologies, including solar photovoltaics, wind power, lithium-ion batteries, and green hydrogen, with detailed spatial and temporal data through 2050 (Figure 14).

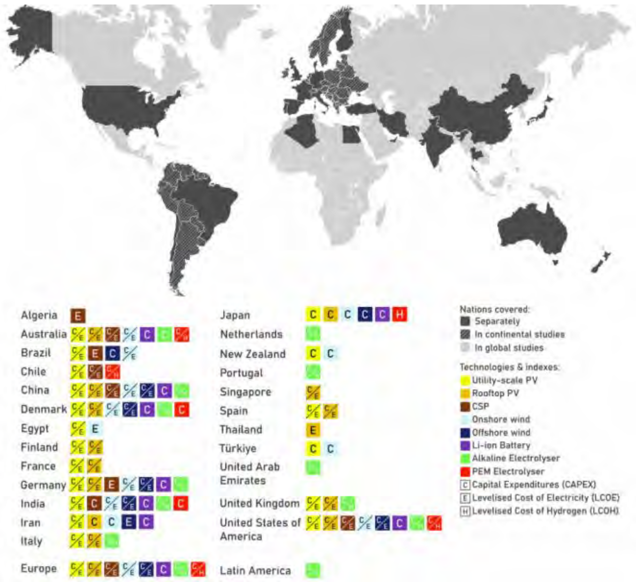

Figure 14. Geographical and technological coverage of the database from Vatankhah Ghadim et al. (2025)

5.3 Policies

The historical trend already contains implemented (trade, industrial and environmental) policies and their implications on the Earth system. The main point concerns how these policies shape the reference scenario, recognizing that a reference scenario cannot be constructed under a no-policy assumption.

Starting with mitigation policies, it is important to acknowledge the extensive work already carried out in past and ongoing projects, such as IAM COMPACT[9], ELEVATE, New PATHWAYS, and in publications like Roelfsema et al. (2025). These initiatives provide curated policy catalogues and detailed implementation protocols, many of which are publicly accessible (e.g., through the NewClimate Institute). The ENTICE project will build on these resources, with a particular focus on the **ELEVATE database**, which offers refined, **model-ready policy representations** and covers most major economies. The emphasis will be on current climate policies at the national level, and on the NDC 2.0 or 3.0 targets/commitments and potentially long-term low-emission development

[9] https://doi.org/10.5281/zenodo.12635301

Funded by the European Union

strategies (LT-LEDS), focusing on unconditional targets. An effort will be made to prioritise key implemented policy measures within the reference scenario. To **extend policies beyond their typical NDC horizon**, there was agreement about using extended historical carbon intensity reductions (Emissions/GDP) rather than extrapolating carbon prices. This approach works even for countries without explicit carbon pricing.

The full ELEVATE climate policy database, including detailed documentation of policy coverage, assumptions, and model implementation, is documented in the Climate Policy Modelling Protocol (Dafnomilis et al., 2025) and is publicly available via Zenodo. For illustrative purposes only, Table 2 reports a selected subset of climate policies included in the CurPol scenario for three major regions (the European Union, the United States, and China). The examples focus on high-mitigation-impact policy categories that are typically represented in ELEVATE and are intended to illustrate how policies are structured by sector, policy instrument, and modelling translation. The table reflects the way ELEVATE organises climate policies into model-ready inputs rather than providing an exhaustive or country-complete overview.

Table 2. Illustrative examples of climate policies included in the ELEVATE CurPol scenario

Region	Sector	Policy instrument	Examples of CurPol policies	Typical modelling representation
European Union	Power generation	Renewable energy targets	Binding targets for the share of renewables in electricity generation	Constraint on renewable electricity share in the power mix
	Power generation/ industry	Carbon pricing	EU Emissions Trading System with declining cap	Explicit carbon price on sector emissions
	Transport	Standards and mandates	CO_2 emission standards for vehicles and biofuel blending mandates	Reduction in energy and carbon intensity of transport demand
	Buildings	Energy efficiency regulation	Energy performance standards and renovation requirements	Reduction in final energy demand in buildings
United States	Transport	Efficiency standards	Fuel efficiency and emissions standards for road transport	Improvement in transport energy and emissions intensity
	Energy supply and use	Energy efficiency regulation	Economy-wide and sectoral energy efficiency improvements	Reduction in final energy demand per unit of output
	Industry (aluminium)	Emissions performance standards	GHG intensity reduction in aluminium production	Reduction in process emissions intensity in aluminium sector

	Buildings	Emissions standards	GHG emissions reduction in buildings sector	Reduction in emissions intensity and final energy demand in buildings
China	Energy and power	Emissions trading system	National emissions trading system covering energy and power sectors	Explicit or implicit carbon price signal in covered sectors
	Transport	Efficiency standards	Energy efficiency and fuel economy standards in the transport sector	Improvement in transport energy and emissions intensity
	Industry (aluminium)	Technology and fuel switching	Increased use of alternative fuels and low-carbon processes in aluminium production	Reduction in emissions intensity through fuel and technology substitution
	Industry (economy-wide)	Emissions intensity targets	GHG emissions intensity reduction targets for industrial production	Constraint on industrial emissions per unit of output

Trade policies, including tariff changes and trade-restrictive measures, are already embedded in the base-year economic datasets typically used in modelling, such as SAMs and the GTAP database. Some efforts may be made to extend the observed past evolution of trade policies to the historical simulation period by drawing on the forthcoming GTAP 2023 database or internal tariff collections. However, fully integrating evolving trade measures into the reference scenario is not considered a viable option. Trade policies tend to change rapidly in recent years, have uncertain long-term persistence, and would require substantial new data collection to update systematically. For these reasons, the reference scenario remains anchored in observed base-year trade policies, while shifts, such as tariff rollbacks, new trade barriers, or deeper liberalisation, are explored through dedicated scenario experiments rather than through the baseline.

Industrial policies lack harmonised, comprehensive databases that can be readily translated into concrete model inputs. Measures such as production subsidies, green-technology incentives, strategic industrial planning, and reshoring initiatives vary significantly across countries and are challenging to quantify in a harmonised manner. Nonetheless, some exploratory work could be undertaken using the information available in existing databases. However, the current guidance is not to impose any assumptions on the future evolution of industrial policies; only the measures reflected in the base and historical years are retained. Beyond this point, no further policy shifts are assumed in the reference scenario. Instead, industrial-policy changes will be explored through targeted policy scenarios or sensitivity analyses, allowing specific interventions to be introduced in a controlled and transparent manner.

Funded by the European Union

5.4 Time horizon

The ENTICE model suite will likely be characterised by different starting years, but whenever possible we expect to use the upcoming GTAP 12 release with 2023 as the base year.

The suitable time horizon for the reference scenario depends on the analytical purpose of the modelling exercise. Trade-oriented assessments often require projections only to the mid-2030s or early 2040s, whereas analyses focused on long-term decarbonisation pathways typically extend to mid-century and beyond. Climate-impact modelling, in particular, benefits from projections that reach the end of the century to capture long-run biophysical and socioeconomic feedback. Considering these differing needs, the reference scenario will have 2050 as a minimum extension, but could also be extended up to 2100, allowing individual models some flexibility according to specific research questions.

Funded by
the European Union

6 Metrics and Indicators for describing the Trade-Industry-Environment nexus

This section presents a structured set of quantitative metrics and indicators intended to characterise the trade–industry–environment nexus within the ENTICE project. The indicators are organised by macro-dimension and are designed to be computable from the outputs of ENTICE models or closely related modelling exercises. The list is intentionally selective rather than exhaustive and aims to provide a common analytical basis for comparing scenarios, interpreting model results, and supporting cross-work-package consistency.

The first group of indicators (Table 3) focuses on **trade-related dimensions**, capturing different aspects of trade openness, trade structure, partner composition, global value chain integration, transport and infrastructure, and trade policy settings.

Table 3. Trade-related indicators for the ENTICE scenario framework

Dimension	Indicator	Formula/Measurement
Trade Openness	Trade-to-GDP ratio	(Exports + Imports) ÷ GDP
Trade Openness	Export share of GDP	Exports ÷ GDP
Trade Openness	Import share of GDP	Imports ÷ GDP
Trade Openness	Import penetration ratio by commodity or type of consumption	Imports/ domestic demand
Trade Openness	Export orientation ratio by commodity or type of consumption	Exports / domestic production
Trade Openness	Shannon diversity index of trade partners (imports)	Sum of partner import shares multiplied by the natural logarithm of each share
Trade Openness	Shannon diversity index of trade partners (export)	Sum of partner export shares multiplied by the natural logarithm of each share
Trade Openness	Import (export) composition by country of origin (destination)	Import (export) by country of origin (destination) over total import (export)
Trade Openness	Herfindahl-Hirschman Index (HHI)	Sum of the squares of the shares (expressed as decimal) of exports by product or country. It ranges between 0 (low concentration) and 1 (maximum concentration).
Trade Openness	Terms of Trade	Ratio between price of exports and price of imports per sector
Trade Openness	Foreign Value Added in Exports (FVA)-backward participation	Foreign value added embedded in exports
Trade Openness	Domestic Value Added in Foreign Exports (DVX)	Domestic value added embedded in foreign countries' exports

Funded by the European Union

Trade Openness	Global Value Chain Participation Index (GVC)	GVC= FVA+DVX
Transport & Infrastructure	Logistics Performance Index	Composite score of logistics efficiency
Transport & Infrastructure	Transport cost index	Average transport cost per ton-km
Domestic Market Size	Population size	Total population
Domestic Market Size	GDP size	Total GDP in USD
Domestic Market Size	Domestic Absorption	DA= C+I+G
Trade Regulation & Policy	Tariff rate (average and by product)	Average (and by product) applied tariff (%)
Trade Regulation & Policy	Non-tariff measures index	Composite index of NTMs
Trade Regulation & Policy	Ease of trading across borders	World Bank Doing Business score
Trade Regulation & Policy	Trade Restrictiveness Index (TRI)	Indicator that sum up tariff and NTBs (translated as ad valorem equivalent) and weighted at sectoral/country level (Weights can be obtained from CGE as World bank for OTRI)
Type of Tradables	Share of goods vs services in exports	Goods exports ÷ total exports × 100
Type of Tradables	High-tech goods share (or technology intensity)	High-tech exports ÷ total goods exports × 100
Type of Tradables	Skill intensity	skilled labour/total labour per sector
Type of Tradables	Tradability Index	(Export+Import)/output (per sector)
Trade Agreements	Number of trade agreements	Count of agreements signed
Trade Agreements	Coverage of trade agreements	Share of trade under agreements (%)
Trading Routes & Reconfiguration	Share of trade by route	Trade volume by route ÷ total trade
Trading Routes & Reconfiguration	Change in route composition	Year-on-year change in route shares
Technology Transfer & Diffusion	FDI inflows in technology sectors	FDI in tech ÷ total FDI
Technology Transfer & Diffusion	Patent licensing agreements	Number of cross-border licensing deals
Trade Partner Composition	Top-5 trade partners share	Trade with top-5 partners ÷ total trade × 100
Trade Partner Composition	Partner diversification index	Concentration index across partners

The second set of indicators (Table 4) describes **industrial structures and dynamics**, with particular attention to production organisation, market concentration, technology and capital

Funded by
the European Union

characteristics, labour outcomes, regional allocation, and linkages between industry, trade, and the macroeconomy.

Table 4. Industry-related indicators for analysing production structures and trade linkages

Dimension	Indicator	Formula/Measurement
Industry Structure & Production Organisation	Sectoral output concentration by region	Share of regional industrial output accounted for by top-N sectors or Herfindahl index across sectors
Industry Structure & Production Organisation	Average price–cost margin / mark-up proxy	Output price ÷ unit cost, by sector and region
Industry Structure & Production Organisation	Intermediate input intensity	Total intermediate inputs ÷ gross output, by sector
Industry Structure & Production Organisation	Herfindahl-Hirschman Index (HHI)	Index for concentration and diversification (it can be for sector output/labour/VA)
Technology, Capital & Production Characteristics	Capital intensity of production	Capital ÷ Labour ratio, by sector
Technology, Capital & Production Characteristics	Total factor productivity – TFP	Level or change in sectoral TFP
Technology, Capital & Production Characteristics	Capital renewal / investment intensity	Investment ÷ capital stock
Labour & Distributional Outcomes	Industrial employment share	Industrial employment ÷ total employment
Labour & Distributional Outcomes	Labour productivity	Value added ÷ employment, by sector
Labour & Distributional Outcomes	Real wage changes in industry-intensive regions	Change in real wages in regions with high industrial employment
Regional Allocation & Industrial Composition	Regional share of industrial output	Share of global or multi-region industrial output produced in each region
Regional Allocation & Industrial Composition	Regional industrial composition	Sector share in total regional industrial output
Regional Allocation & Industrial Composition	Revealed regional specialisation index	Sector share in region ÷ sector share globally (production)
Regional Allocation & Industrial Composition	Location Quotient (LQ)	sectoral VA share over total VA in country i/sectoral VA share over total VA in World
Macro–Industry Linkages	Industrial value-added share of GDP	Industrial value added ÷ GDP
Macro–Industry Linkages	Contribution of industry to GDP growth	Contribution of changes in industrial value added to overall GDP growth
Trade – Export Specialisation	Revealed comparative advantage – RCA	Balassa index computed from sectoral exports
Trade – GVC Integration	Imported intermediate share	Imported intermediates ÷ total intermediates

Funded by the European Union

Trade – GVC Integration	Multiregional backward linkages – MRIO	Leontief inverse–based measures by origin
Trade – GVC Integration	Foreign value added embodied in production	Foreign value added embodied in domestic production
Trade – GVC Integration	Intermediate vs final exports	Share of exports absorbed as intermediate demand abroad
Trade – Exposure & Resilience	Import penetration ratio	Imports ÷ domestic absorption
Trade – Exposure & Resilience	Export market diversification index	Concentration index across export destinations
Trade – Exposure & Resilience	Terms-of-trade effects for industrial goods	Change in export prices relative to import prices for industrial goods
Environmental Performance	Direct emissions intensity	Emissions ÷ gross output, by sector
Environmental Performance	Indirect emissions intensity, scope 2 (and 3)	Direct emissions plus emissions embodied in electricity generation (plus all embodied) ÷ gross output, by sector
Environmental Performance	Energy intensity	Energy use ÷ value added
Environmental Performance	Carbon cost exposure	Carbon payments ÷ value added
Environmental Performance	Industry contribution to emissions reduction	Contribution of industrial sectors to total emissions change
Resource Availability & Dependency	Share of critical inputs in production costs	Cost share of energy, minerals and materials
Resource Availability & Dependency	Import dependency for key resources	Imports ÷ total use of critical resources

The third group of indicators (Table 5) focuses on **environmental outcomes**, covering greenhouse gas emissions, resource and energy use, land-use change, biodiversity, pollution, circular economy dimensions, and critical raw materials.

Table 5. Environmental indicators for assessing climate and non-climate impacts

Dimension	Indicator	Formula/Measurement
GHG Emissions	Total GHG emissions	Sum of CO_2e from all sources
GHG Emissions	GHG emissions per capita	Total GHG emissions ÷ Population
GHG Emissions	GHG emissions per unit GDP	Total GHG emissions ÷ GDP
GHG Emissions	Direct emissions due to trade	Emissions from freight
GHG Emissions	GHG emissions intensity of trade	GHG emissions embodied in import (export) ÷ import (export)
Land-Use Change	Deforestation rate	Hectares lost per year
Land-Use Change	Net land-use emissions	CO_2e from land-use change
Land-Use Cover	Forest cover %	Forest area ÷ Total land area × 100
Sectoral Emission Intensity	Emissions per unit of output	Sector emissions ÷ Sector output
Sectoral Emission Intensity	Emissions per kWh	Energy sector emissions ÷ Electricity generated
Water Use	Total freshwater withdrawal	m^3/year

Funded by the European Union

Water Use	Water intensity	Water use ÷ GDP or output
Water Use	Wastewater treatment rate	Treated wastewater ÷ Total wastewater × 100
Energy & Resource Consumption	Total energy consumption	TJ/year
Energy & Resource Consumption	Energy intensity of GDP	Energy use ÷ GDP
Energy & Resource Consumption	Material footprint (e.g. steel, aluminium, cement, etc.)	Tons per capita
Biodiversity	Species richness index	Count of species per area
Biodiversity	Biodiversity intactness index	% original biodiversity remaining
Biodiversity	Mean Species Abundance (MSA)	
Biodiversity	Red List Index	Weighted score of threatened species
Biodiversity	Protected area coverage	Protected land ÷ Total land × 100
Pollution	PM2.5 concentration	µg/m³
Pollution	Water pollutant levels	BOD, nitrates, heavy metals
Pollution	Plastic leakage	Tons/year
Circular Economy	Recycling rate	Recycled waste ÷ Total waste × 100
Circular Economy	Secondary raw material share	Secondary materials ÷ Total materials × 100
Critical Raw Materials	Extraction volume	Tons/year
Critical Raw Materials	Share of recycled critical materials (e.g. steel, aluminium, copper)	Recycled ÷ Total demand × 100
Environmental Regulation & Policy	Carbon pricing coverage	% of emissions under carbon pricing
Carbon price	Carbon price	$/tCO2

An overview mapping these indicators to the individual ENTICE models, indicating which indicators can be produced by each modelling framework, is provided in Annex B. This mapping will be progressively refined over the course of ENTICE, evolving alongside modelling developments, data improvements, and scenario analyses.

Funded by the European Union

7 Conclusions

This deliverable outlines a structured framework for developing coherent, policy relevant futures at the intersection of trade, industry, climate, and the environment. Its objective has been to transform a wide range of qualitative inputs, gathered through the Scenario Definition Workshop, into a consistent conceptual basis that will guide subsequent modelling and analytical work across the project's work packages. By combining workshop insights, a systematic review of scenario dimensions, and a carefully designed reference narrative, the deliverable establishes the methodological foundations for analyzing how global economic and policy dynamics may evolve and interact over the coming decades.

The Scenario Definition Workshop played a central role in shaping this framework. Participants from diverse disciplinary backgrounds converged on a shared understanding of scenario design as an exercise rooted in managing deep uncertainty, articulating explicit assumptions, and ensuring coherence between narrative elements and their quantitative representation. Discussions highlighted that the trade–industry–environment nexus cannot be meaningfully explored within traditional scenario frameworks that treat trade as a background variable or isolate climate and industrial dynamics. Instead, ENTICE adopts a layered scenario design that brings these interdependencies to the forefront. Through a combination of plenary perspectives and macro-dimension-specific breakout sessions, the workshop identified the dimensions most critical for future evolution: degrees of trade openness and regulatory symmetry, the organization and fragmentation of global value chains, market concentration and firm heterogeneity, the ambition and scope of climate and environmental protection, and the pace of technological and socio-institutional transformation.

Building on this foundation, the deliverable moves from a list of dimensions to a structured scenario space, organized around major pathways that capture contrasting configurations of global integration, industrial organization, environmental ambition, and enabling conditions. This architecture allows ENTICE to explore a wide range of pathways without multiplying baselines. Then, three archetypal narratives were developed, Coordinated Globalization, Regionalized Fragmentation, and Fragmented Isolation, representing stylized yet internally consistent visions of how the world might evolve under different combinations of cooperation, geopolitical alignment, industrial structure, and environmental commitment. These narratives are not intended as predictions but as analytical lenses that illuminate the diverse channels through which trade, industrial policy, and environmental pressures interact.

A key contribution of the deliverable is translating these qualitative archetypes into forms suitable for quantitative modelling through a layered approach. The operationalization of each narrative specifies the structural assumptions, parameter choices, and institutional mechanisms that would reproduce the logic of each storyline within the modelling tools applied in ENTICE. This process clarifies how alternative future configurations, whether highly integrated and cooperative, regionally coordinated, or fragmented and protectionist, affect trade costs, substitution elasticities, technology diffusion, production structures, environmental outcomes, and governance effectiveness. By linking narrative elements to explicit modelling levers, the deliverable ensures transparency and consistency across the models in WP4 and supports a meaningful comparison of results.

The deliverable also defines a unified reference scenario to be used across all modelling exercises. ENTICE anchors this reference to an updated SSP2 ("Middle of the Road") pathway, aligning historical data up to 2025 with recent GDP and population trends and then applying SSP2 growth rates thereafter. Complementary assumptions regarding energy prices, extractive materials, and technology costs are drawn from authoritative sources, helping to clarify the broader set of inputs that will inform and shape the ENTICE reference scenario. Policies already implemented will be incorporated into the ENTICE reference scenario, drawing on the recently published ELEVATE Climate Policy Modelling Protocol. In contrast, trade and industrial policies are kept as observed in the base and historical years. This approach maintains realism without embedding uncertain future policy shifts into the baseline, leaving such developments to be explored through dedicated policy experiments.

The document concludes by presenting a structured set of quantitative metrics and indicators linked to the trade–industry–environment dimensions that guided the work of T4.1 from the initial workshop to the development of the narratives. These indicators, to be produced by the ENTICE model ensemble, provide a common analytical basis for scenario comparison, interpretation of model outputs, and ensuring consistency across work packages.

Overall, the deliverable provides the conceptual, methodological, and empirical foundations needed to support the modelling and analytical work that follows. It establishes a clear reference trajectory, delineates the broader scenario space through archetypal pathways, and sets out a transparent operational framework for translating narratives into quantitative terms. By doing so, it ensures that ENTICE's analysis of the trade–industry–environment nexus will be coherent, comparable across models, and robust to uncertainty, allowing the project to explore not only how current trends may play out, but also how alternative configurations of policy, governance, technology, and global integration could reshape economic and environmental futures.

Next steps:

- The work on the reference scenario will continue until the end of Task 4.1 and will involve computing updated SSP2 trajectories for the main drivers, as well as extending the reference values for other drivers. This will support models in developing coherent projections for the endogenous variables of interest.
- Following the illustrative example of the three archetypal narratives, we will co-design with the teams participating in the task the narratives we would like to contrast with the reference scenario.
- Then for each narrative we will identify the elements of the dimensions that are instrumental to the analysis in the modelling exercises considering the models' capability to capture several of the layers shaping the narratives.
- After having agreed upon elements to introduce, we will discuss models' levers to be used and establish a protocol to ensure harmonization across models and enhancing comparability of results.

Funded by the European Union

- Levers will be quantified for their application in the modelling exercise.

Funded by
the European Union

ANNEX

Annex A Workshop agenda

	Workshop agenda			
14:00- 14:05	**Welcome and project presentation** ENTICE project coordinator Dr. Panagiotis F.			
14:05- 14:10	**Framing the linkage between Trade, Climate, and Industry**			
14:10- 14:20	**Presentation 1:** Richard Baron (ECF)			
14:20- 14:30	**Presentation 2:** Antoine Oger (IEEP)			
14:30- 14:40	**Presentation 3:** Eddy Bekkers (WTO)			
14:40- 14:50	**Presentation 4:** Cecilia Bellora (OECD)			
14:50- 15:20	**Brainstorming and discussion**			
15:20- 15:30	**Break**			
15:30- 15:40	**Introduction to scopes of breakout sessions ***			
15:40- 16:30	**Breakout session #1** **Trade**	**Breakout session #2** **Industry**	**Breakout session #3** **Environment**	**Breakout session #4** **Socioeconomic drivers & enablers**

Funded by the European Union

16:30- 17:00	**Reporting back from breakout sessions and concluding remarks**

Funded by
the European Union

Annex B Mapping indicators to models

The following tables list the indicators proposed in Section 6, mapping them with ENTICE suite of modelling tools.

Table 6. Trade indicators available in ENTICE suite of modelling tools

Indicator	NEMESIS EU	NEMESIS World	ICES	ZEW Model	DYNERIO	LBAM	GEM-E3	FIDELIO	GLOBIOM	OPEN-PROM	IMAGE	GEMINI-E3	SORMAC-25	ENVISAGE
Trade-to-GDP ratio	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Export share of GDP	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes		No	Yes	Yes	Yes
Import share of GDP	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes		No	Yes	Yes	Yes
Import penetration ratio by commodity or type of consumption	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Expected during ENTICE	Yes	Yes	Expected during ENTICE	Yes
Export orientation ratio by commodity or type of consumption	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Expected during ENTICE	No	Yes	Expected during ENTICE	Yes
Shannon diversity index of trade	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Expected during ENTICE	No	Yes	Yes	Yes

Funded by
the European Union

Indicator	NEMESIS EU	NEMESIS World	ICES	ZEW Model	DYNERIO	LBAM	GEM-E3	FIDELIO	GLOBIOM	OPEN-PROM	IMAGE	GEMINI-E3	SORMAC-25	ENVISAGE
partners (imports)														
Shannon diversity index of trade partners (export)	No	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Expected during ENTICE	No	Yes	Yes	Yes
Import (export) composition by country of origin (destination)	No	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Expected during ENTICE	No	Yes	Yes	Yes
Herfindahl-Hirschman Index (HHI)	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Expected during ENTICE		Yes	No	Yes
			Yes											
Terms of Trade	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No		No	Yes	No	Yes
Foreign Value Added in Exports (FVA)-backward participation	No	Expected during ENTICE	Yes	Expected during ENTICE	Expected during ENTICE	No	Expected during ENTICE	Expected during ENTICE	No		No	Expected during ENTICE	No	Yes
Domestic Value Added in Foreign Exports (DVX)	No	Expected during ENTICE	Yes	Expected during ENTICE	Expected during ENTICE	No	Expected during ENTICE	Expected during ENTICE	No		No	Expected during ENTICE	No	Yes

Funded by the European Union

Indicator	NEMESIS EU	NEMESIS World	ICES	ZEW Model	DYNERIO	LBAM	GEM-E3	FIDELIO	GLOBIOM	OPEN-PROM	IMAGE	GEMINI-E3	SORMAC-25	ENVISAGE
Global Value Chain Participation Index (GVC)	No	Expected during ENTICE	Yes	Expected during ENTICE	No	No	Expected during ENTICE	Expected during ENTICE	No		No	Expected during ENTICE	No	Yes
Logistics Performance Index	No	No	No	No	No	No	No	No	No		No	No	No	No
Transport cost index	No	No	No	No	No	No	No	No	No	No	No	Expected during ENTICE	Expected during ENTICE	No
Population size	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
GDP size	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Domestic Absorption	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No		No	Yes	Yes	Yes
Tariff rate (average and by product)	Expected during ENTICE	Expected during ENTICE	Yes	Expected during ENTICE	No	Yes	Yes	Expected during ENTICE	Yes	Expected during ENTICE	No	Yes	Expected during ENTICE	Yes
Non-tariff measures index	Expected during ENTICE	Expected during ENTICE	Yes	No	No	No	No	Expected during ENTICE	Expected during ENTICE		No	Expected during ENTICE	No	Yes
Ease of trading across borders	No	No	No	No	No	No	No	No	No	Expected during ENTICE	No	No	No	No
Trade Restrictiveness Index (TRI)	Expected during ENTICE	Expected during ENTICE	Yes	No	No	No	No	Expected during ENTICE	Expected during ENTICE		No	Expected during ENTICE	No	Yes
Share of goods	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No		No	Yes	No	Yes

Funded by
the European Union

Indicator	NEMESIS EU	NEMESIS World	ICES	ZEW Model	DYNERIO	LBAM	GEM-E3	FIDELIO	GLOBIOM	OPEN-PROM	IMAGE	GEMINI-E3	SORMAC-25	ENVISAGE
vs services in exports														
High-tech goods share (or technology intensity)	No	No	Expected during ENTICE	No	No	No	No	No	No		No	Expected during ENTICE	No	Expected during ENTICE
Skill intensity	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No		No	No	No	Yes
Tradability Index	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		No	Yes	Yes	Yes
Number of trade agreements	No	No	No	No	No	No	No	No	No		No	No	No	No
Coverage of trade agreements	No	No	No	No	No	No	No	No	No		No	No	No	No
Share of trade by route	No	No	No	No	No	No	No	No	No		No	No	Not yet but expected during ENTICE	No
Change in route composition	No	No	No	No	No	No	No	No	No		Yes	No	No	No
FDI inflows in technology sectors	No	Expected during ENTICE	No	No	No	No	Expected during ENTICE	No	No		No	No	Yes	No
Patent licensing agreements	No	No	No	No	No	No	No	No	No		No	No	No	No

Funded by the European Union

Indicator	NEMESIS EU	NEMESIS World	ICES	ZEW Model	DYNERIO	LBAM	GEM-E3	FIDELIO	GLOBIOM	OPEN-PROM	IMAGE	GEMINI-E3	SORMAC-25	ENVISAGE
Top-5 trade partners share	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes		No	Yes	Yes	Yes

Table 7. Industry indicators available in ENTICE suite of modelling tools

Indicator	NEMESIS EU	NEMESIS World	ICES	ZEW Model	DYNERIO	LBAM	GEM-E3	FIDELIO	GLOBIOM	OPEN-PROM	IMAGE	GEMINI-E3	SORMAC-25	ENVISAGE
Sectoral output concentration by region	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	No	Yes
Average price–cost margin / mark-up proxy	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	No	No	No	
Intermediate input intensity	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes
Herfindahl-Hirschman Index (HHI)	No	Yes	Yes	Yes	Expected during ENTICE	No	Yes	Yes	No	Expected during ENTICE	No	No	No	Yes
Capital intensity of production	Yes	Yes	Yes	Yes	Yes		Yes	Yes	No	No	No	Yes	No	Yes
Total factor productivity –	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	No	No	Yes	No	Yes

Funded by the European Union

Indicator	NEMESIS EU	NEMESIS World	ICES	ZEW Model	DYNERIO	LBAM	GEM-E3	FIDELIO	GLOBIOM	OPEN-PROM	IMAGE	GEMINI-E3	SORMAC-25	ENVISAGE
TFP														
Capital renewal / investment intensity	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Expected during ENTICE	No	Yes	Yes	Yes
Industrial employment share	Yes	Yes	Yes	Yes	Yes		Yes	Yes	No	Expected during ENTICE	No	Yes	No	Yes
Labour productivity	Yes	Yes	Yes	Yes	Yes		Yes	Yes	No	Expected during ENTICE	No	No	No	Expected during ENTICE
Real wage changes in industry-intensive regions	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	No	No	Yes	No	Yes
Regional share of industrial output	No	Yes	Yes		Yes	Yes	Yes	Yes	No	Yes	No	Yes	No	Yes
Regional industrial composition	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No	Yes
Revealed regional specialisation index	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
Location Quotient (LQ)	No	Yes	Yes	Yes	Yes		Yes	Yes	No	Expected during ENTICE	No	Yes	No	Yes
Industrial	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	No	Yes

Funded by the European Union

Indicator	NEMESI S EU	NEMESI S World	ICES	ZEW Model	DYNERI O	LBA M	GEM-E3	FIDELIO	GLOBIO M	OPEN-PROM	IMAGE	GEMINI-E3	SORMAC -25	ENVISAG E
value-added share of GDP														
Contribution of industry to GDP growth	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	No	Yes
Revealed comparative advantage – RCA	No	Yes	Yes	Yes	No		Yes	Yes	No		No	Yes	No	Yes
Imported intermediate share	No	No	Yes	Yes	Yes		Yes	Yes	No		No	Yes	No	Yes
Multiregional backward linkages – MRIO	No	No	Yes	Expecte d during ENTICE	Yes	No	Yes	Yes	No	No	No	Yes	No	Yes
Foreign value added embodied in production	No	Expecte d during ENTICE	Yes	Expecte d during ENTICE	Yes	No	Yes	Expecte d during ENTICE	No	No	No	Yes	No	Yes
Intermediate vs final exports	No	Expecte d during ENTICE	Yes	Expecte d during ENTICE	Expected during ENTICE	No	Yes	Expecte d during ENTICE	No	No	No	Yes	No	Yes
Import penetration ratio	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	No	No	Yes	Yes	Yes
Export market diversification index	No	Yes	Yes	Yes	No	No	Yes	Yes	No	No	No	Yes	Yes	Yes
Terms-of-trade effects for	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	No	Yes	No	Yes

Funded by
the European Union

Indicator	NEMESIS EU	NEMESIS World	ICES	ZEW Model	DYNERIO	LBAM	GEM-E3	FIDELIO	GLOBIOM	OPEN-PROM	IMAGE	GEMINI-E3	SORMAC-25	ENVISAGE
industrial goods														
Direct emissions intensity	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
Indirect emissions intensity, scope 2 (and 3)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No	Yes
Energy intensity	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Carbon cost exposure	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Industry contribution to emissions reduction	Yes	Yes	Yes	Yes	Yes		Yes	Yes	No	Yes	No	Yes	No	Yes
Share of critical inputs in production costs	Expected during ENTICE	Expected during ENTICE	Expected during ENTICE	No	Expected during ENTICE	No	Expected during ENTICE	Expected during ENTICE	No	No	No	Expected during ENTICE	Expected during ENTICE	Yes
Import dependency for key resources	Expected during ENTICE	Expected during ENTICE	Expected during ENTICE	No	Yes	No	Expected during ENTICE	Expected during ENTICE	No	Yes	Expected during ENTICE	Expected during ENTICE	Expected during ENTICE	Yes

Table 8. Environmental indicators available in ENTICE suite of modelling tools

Indicator	NEMESIS EU	NEMESIS World	ICES	ZEW Model	DYNERIO	LBAM	GEM-E3	FIDELIO	GLOBIOM	OPEN-PROM	IMAGE	GEMINI-E3	SORMAC-25	ENVISAGE
Total GHG emissions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Expected during ENTICE	Yes

Funded by the European Union

Indicator	NEMESIS EU	NEMESIS World	ICES	ZEW Model	DYNERIO	LBAM	GEM-E3	FIDELIO	GLOBIOM	OPEN-PROM	IMAGE	GEMINI-E3	SORMAC-25	ENVISAGE
GHG emissions per capita	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Expected during ENTICE	Yes
GHG emissions per unit GDP	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Expected during ENTICE	Yes
Direct emissions due to trade	Yes	No	Yes	No	Expected during ENTICE	No	Yes	Expected during ENTICE	No	Yes	Yes	Expected during ENTICE	Expected during ENTICE	Yes
GHG emissions intensity of trade	No	Expected during ENTICE	Yes	Expected during ENTICE	Expected during ENTICE	Yes	Yes	Expected during ENTICE	Yes	Expected during ENTICE	No	Yes	Expected during ENTICE	Yes
Deforestation rate	No	Expected during ENTICE	No	No	No	No	No	No	Yes	Yes	Yes	No	No	No
Net land-use emissions	No	Expected during ENTICE	Expected during ENTICE	No	No	No	No	No	Yes	Yes	Yes	No	No	No
Forest cover %	No	Expected during ENTICE	Expected during ENTICE	No	No	No	No	No	Yes	Yes	Yes	No	No	No
Emissions per unit of output	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
Emissions per kWh	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Total freshwater	No	Expected during	No	No	No	No	No	No	No	No	Yes	No	No	No

Indicator	NEMESIS EU	NEMESIS World	ICES	ZEW Model	DYNERIO	LBAM	GEM-E3	FIDELIO	GLOBIOM	OPEN-PROM	IMAGE	GEMINI-E3	SORMAC-25	ENVISAGE
withdrawal		ENTICE												
Water intensity	No	Expected during ENTICE	No	No	No	No	No	No	No	No	Yes	No	No	No
Wastewater treatment rate	No	Expected during ENTICE	No	No	No	No	No	No	No	No	Expected during ENTICE	No	No	No
Total energy consumption	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Energy intensity of GDP	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Material footprint (e.g. steel, aluminium, cement, etc.)	Expected during ENTICE	Expected during ENTICE	Expected during ENTICE	No	Yes	No	Expected during ENTICE	Expected during ENTICE	No	Expected during ENTICE	Yes	Expected during ENTICE	No	Yes
Species richness index	No	No	No	No	No	No	Yes	No	No	Expected during ENTICE	No	No	No	No
Biodiversity intactness index	No	Expected during ENTICE	No	No	No	No	No	No	Yes	Expected during ENTICE	Yes	No	No	No
Mean Species Abundance (MSA)	No	No	No	No	No	No	Yes	No	Yes	No	Yes	No	No	No

Funded by
the European Union

Indicator	NEMESIS EU	NEMESIS World	ICES	ZEW Model	DYNERIO	LBAM	GEM-E3	FIDELIO	GLOBIOM	OPEN-PROM	IMAGE	GEMINI-E3	SORMAC-25	ENVISAGE
Red List Index	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Protected area coverage	No	Expected during ENTICE	No	No	No	No	No	No	Yes	No	Yes	No	No	No
PM2.5 concentration	No	No	No	No	No	No	No	No	No	No	Expected during ENTICE	No	No	Yes
Water pollutant levels	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Plastic leakage	No	No	Expected during ENTICE	No	No	No	No	No	No	No	No	No	No	No
Recycling rate	No	No	Expected during ENTICE	No	Expected during ENTICE	No	Expected during ENTICE	Expected during ENTICE	No	No	Yes	Expected during ENTICE	No	Expected during ENTICE
Secondary raw material share	No	No	Expected during ENTICE	No	No	No	Expected during ENTICE	Expected during ENTICE	No	Expected during ENTICE	Yes	Expected during ENTICE	No	Yes
Extraction volume	No	No	Expected during ENTICE	No	Yes	No	Expected during ENTICE	Expected during ENTICE	No	Expected during ENTICE	Expected during ENTICE	Expected during ENTICE	Expected during ENTICE	Yes
Share of recycled critical materials (e.g. steel, aluminium,	No	Expected during ENTICE	Expected during ENTICE	No	Yes	No	Expected during ENTICE	Expected during ENTICE	No	No	Expected during ENTICE	Expected during ENTICE	No	Yes

Funded by the European Union

Indicator	NEMESIS EU	NEMESIS World	ICES	ZEW Model	DYNERIO	LBAM	GEM-E3	FIDELIO	GLOBIOM	OPEN-PROM	IMAGE	GEMINI-E3	SORMAC-25	ENVISAGE
copper)														
Carbon pricing coverage	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Carbon price	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Nitrogen use	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Expected during ENTICE	Yes

Bibliography

Dafnomilis, I., Hooijschuur, E., Schmidt Tagomori, I., van Soest, H., Roelfsema, M., den Elzen, M. (2025). *Climate Policy Modelling Protocol*. ELEVATE Project. Zenodo. https://doi.org/10.5281/zenodo.17854618

European Commission (2021), EU Reference Scenario 2020, Energy, transport and GHG emissions - Trends to 2050, https://energy.ec.europa.eu/data-and-analysis/energy-modelling/eu-reference-scenario-2020_en

Fragkos, P., Zisarou, E., Van De Ven, D.-J., Mittal, S., *et al.* (2025). *A multi-model assessment of technological constraints on Europe's energy transition* (Version 1). Preprint. https://doi.org/10.21203/rs.3.rs-7848475/v1

Guillemette, Y. (2025), OECD global long-run economic scenarios 2025 update, OECD Economic Policy Papers, N°36

International Monetary Fund. World Economic Outlook (WEO), https://data.imf.org/en/datasets/IMF.RES:WEO. Accessed on [current date].

IEA 2025, World Energy Outlook 2025, International Energy Agency, Paris (https://www.iea.org/reports/world-energy-outlook-2025)

Lundaev, V., Solomon, A. A., Le, T., Lohrmann, A., & Breyer, C. (2023). Review of critical materials for the energy transition, an analysis of global resources and production databases and the state of material circularity. Minerals Engineering, 203, 108282. https://doi.org/10.1016/j.mineng.2023.108282

Keramidas, K., Fosse, F., Aycart Lazo, F. J., Dowling, P., Garaffa, R., Ordonez, J., Petrovic, S., Russ, P., Schade, B., Schmitz, A., Soria Ramirez, A., van der Vorst, C., & Weitzel, M. (2025). *Global Energy and Climate Outlook 2024* (JRC139986). Publications Office of the European Union. https://data.europa.eu/doi/10.2760/9028706

O'Neill, B. C., Kriegler, E., Riahi, K., Ebi, K. L., Hallegatte, S., Carter, T. R., Mathur, R., & van Vuuren, D. P.(2014). A new scenario framework for climate change research: the concept of shared socioeconomic pathways. Climatic Change, 122, 387–400. https://doi.org/10.1007/s10584-013-0905

O'Neill, B. C., Kriegler, E., Ebi, K. L., Kemp-Benedict, E., Riahi, K., Rothman, D. S., van Ruijven, B. J., van Vuuren, D. P., Birkmann, J., Kok, K., Levy, M., & Solecki, W. (2017). The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. Global Environmental Change, 42, 169–180. https://doi.org/10.1016/j.gloenvcha.2015.01.004

Popp, A., Calvin, K., Fujimori, S., Havlik, P., Humpenöder, F., Stehfest, E., Bodirsky, B. L., Dietrich, J. P., Doelmann, J. C., Gusti, M., Hasegawa, T., Kyle, P., Obersteiner, M., Tabeau, A., Takahashi, K., Valin, H., Waldhoff, S., Weindl, I., Wise, M., Kriegler, E., & van Vuuren, D. P. (2017). Land-use futures in the shared socio-economic pathways. Global Environmental Change, 42, 331–345. https://doi.org/10.1016/j.gloenvcha.2016.10.002

Riahi, K., van Vuuren, D. P., Kriegler, E., Edmonds, J., O'Neill, B. C., Fujimori, S., Bauer, N., Calvin, K., Dellink, R., Fricko, O., Lutz, W., Popp, A., Cuaresma, J. C., KC, S., Leimbach, M., Jiang, L., Kram, T., Rao, S., Emmerling, J., Ebi, K., Hasegawa, T., Havlik, P., Humpenöder, F., Silva, L. A., Smith, S., Stehfest, E., Bosetti, V., Eom, J., Gernaat, D., Masui, T., Rogelj, J., Strefler, J., Drouet, L., Krey, V., Luderer, G., Harmsen, M., Takahashi, K., Baumstark, L., Doelman, J. C., Kainuma, M., Klimont, Z., Marangoni, G., Lotze-Campen, H., Obersteiner, M., Tabeau, A., & Tavoni, M. (2017). The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. Global Environmental Change, 42, 153–168

Roelfsema, M., van Soest, H.L., Harmsen, M. et al. Taking stock of national climate policies to evaluate implementation of the Paris Agreement. Nat Commun 11, 2096 (2020). https://doi.org/10.1038/s41467-020-15414-6

van Heerden, R., Edelenbosch, O.Y., Daioglou, V. *et al.* Demand-side strategies enable rapid and deep cuts in buildings and transport emissions to 2050. *Nat Energy* **10**, 380–394 (2025). https://doi.org/10.1038/s41560-025-01703-1

Vatankhah Ghadim, H., Haas, J., Breyer, C. *et al.* Clean technology cost projections: investment and levelized costs of solar, wind, battery, and hydrogen. *Sci Data* **12**, 1670 (2025). https://doi.org/10.1038/s41597-025-05951-4