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NEXOGENESIS
STREAMLINING WATER RELATED POLICIES

D4.3 Simulation policy framework

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Project Deliverable

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D4.3 Simulation policy framework

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Abstract

Deliverable D4.3 *Simulation policy framework* is classified as a "Demonstrator." This document is intended to accompany the deliverable, providing explanations about the Simulation Policy Framework (SPF) design, functionalities, development and technical aspects to complement the developed digital solutions as a result of the task T4.3 *Modelling of potential WEFE nexus impacts and stakeholder's response.*

The SPF is a crucial component of the Nexogenesis project, acting as the primary mechanism for simulating the impacts of policies and policy packages on the nexus. This allows for analysis at various spatial and temporal scales. The SPF is the result of extensive cross-collaboration within the NXG co-creation framework, involving multiple technical Work Packages (WP1 to WP5). It integrates key NXG outcomes, such as case study policies and goals, the System Dynamic Models (implemented for all proposed combinations of Shared Socioeconomic Pathways and Representative Concentration Pathways), and the Nexus footprint index. All this nexus related resources all accessible through the SLNAE UI.

The current version of the Simulation Policy Framework is embedded into the public release of the SLNAE at the following urls: https://slnae-dev.nexogenesis.eu or https://nepat-dev.nexogenesis.eu

The SLNAE acronym, which is the reference to this tool in the Grant Agreement, has been changed to NEPAT (Nexus Policy Assessment Tool), during the project. This was decided because it was easier to pronounce than SLNAE and also it reflected better for the general audience the content of the tool. In this document, the two acronyms SLNAE and NEPAT are both being used indiscriminately and they refer to the same tool. This has been done on purpose, because SLNAE is mentioned in the Grant Agreement and also because several related actions have started and happened under with the tool named SLNAE, while now, more recent activities are referring to NEPAT and this document is an intermediate report for this tool. By the end of the project, NEPAT will be the name of this tool.

Related Deliverables:
D3.4 Complexity science models implemented for all the Case Studies including explanatory manuals
D3.6 Sensitivity/Uncertainty Analysis Report
D4.1 Self-learning nexus engine specifications and technical design

Keywords
SLNAE; NEPAT, Policy integration, Policy impact evaluation, UI

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Abbreviation/Acronyms

AI	Artificial Intelligence
API	Application Protocol Interface
CS	Case Study
DSS	Decision Support System
GUI/UI	Graphical User Interface/User Interface
HTTPS	Hypertext Transfer Protocol Secure
ICT	Information and Communication Technologies
JSON	JavaScript Object Notation
NEPAT	NExogenesis Policy Assessment Tool
NXG	Nexogenesis project
SDGs	Sustainable Development Goals
SDM	System Dynamic Model
SLNAE	Self-Learning Nexus Assessment Engine
SH	Stakeholder
RDF	Resource Description Framework
REST	Representational State Transfer
WEFE	Water-Energy-Food-Ecosystem
WS	Workshop

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1. Introduction

The Simulation Policy Framework (SPF) constitutes a key component across the Nexogenesis project. It serves as the fundamental mechanism enabling the simulation of policies and policy packages' impacts on the nexus, facilitating analysis at different spatial and temporal scales, and supporting additional advanced functionalities such as the Nexogenesis Decision Support System (DSS) (see deliverable D4.4 *Core module of the self-learning nexus engine*).

The SPF is the culmination of long-term cross-collaboration within the NXG co-creation framework (Figure 1 - Left), among technical Work Packages, from WP1 to WP5. Here, all the WPs' outcomes converge, as despised in the right diagram of Figure 1. On one side, WP1 and WP5, along with CSs and SHs, have identified and provided all the policies and goals that should be implemented and available in the Self-Learning Nexus Assessment Engine (SLNAE). In parallel, WP2 has collected the underlying climate and socio-economic data required to build the complexity science models. Subsequently, WP3 has integrated all this data and generated the System Dynamic Models (SDMs), incorporating policies, goals and the WEFE footprint. Finally, as a result of the task T4.3 *Modelling of potential WEFE nexus impacts and stakeholder's response*, WP4 has integrated the SDMs into the SLNAE, making them accessible through the SLNAE User Interface (UI) and the REpresentational State Transfer Application Protocol Interface (REST API).

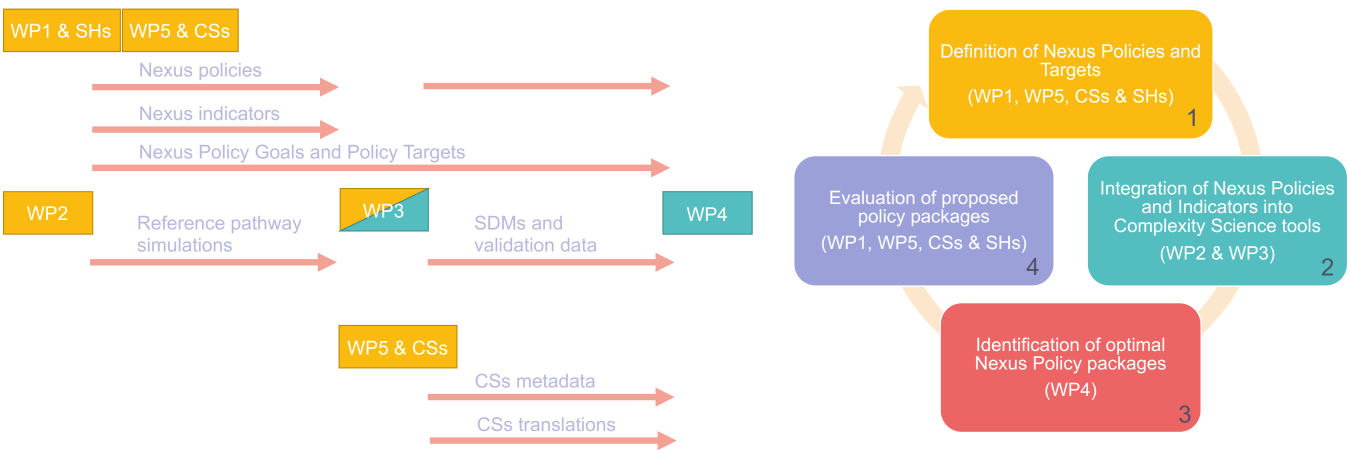

Figure 1. Left: NXG cross-WP data and developments pipeline. Right: NXG co-creation framework for Nexus Policy packages identification. Source: D4.1

Thanks to the SPF, the NXG's SHs can interact with the SLNAE to evaluate the impact of different policy packages in any of the five NXG's CSs. Through the SLNAE UI (Figure 2) users can obtain different insights and conduct in-deep analysis of different policy packages configurations to assess their performance against the CSs' goals or the Nexus footprint index.

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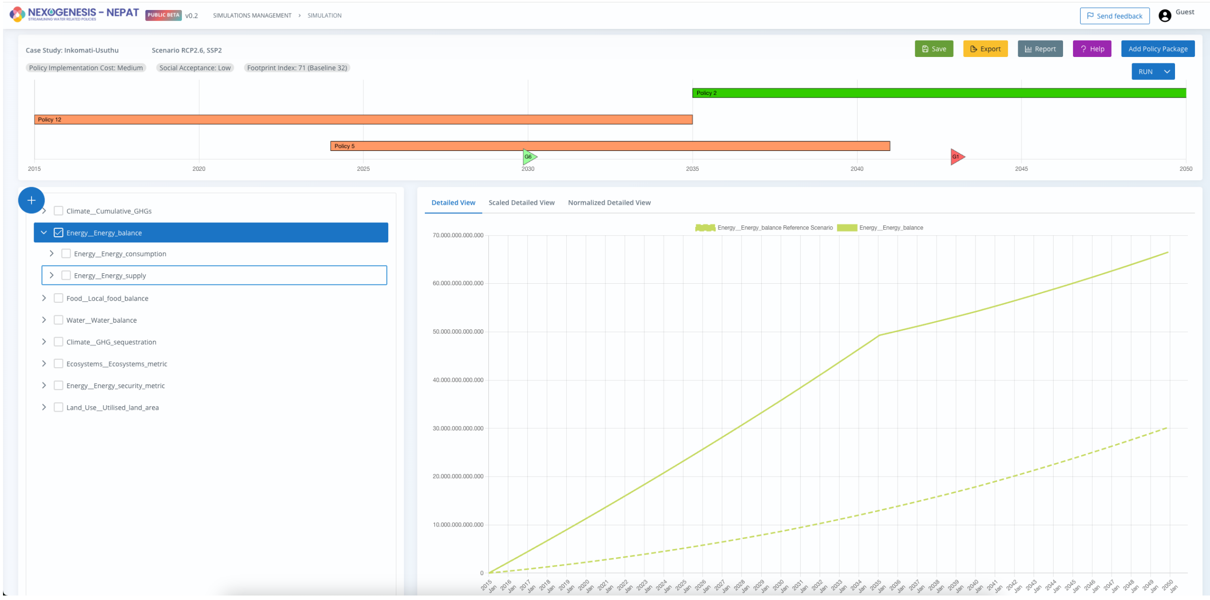

Figure 2. SLNAE UI. Detailed view where the impact of a policy package is evaluated.

Deliverable D4.3 *Simulation policy framework* is classified as a "Demonstrator." This document accompanies the deliverable and offers detailed explanations about the design, functionalities, development, and technical aspects of the SPF. It is intended to complement the digital solutions developed from Task T4.3 *Modelling of potential WEFE nexus impacts and stakeholder's response.*

The current version of the Simulation Policy Framework is embedded into the public release of the SLNAE at the following urls: https://slnae-dev.nexogenesis.eu or https://nepat-dev.nexogenesis.eu

1.1. Disclaimer

The public version of the SLNAE is currently under development and has been designated as a Beta version (Figure 3). All its modules, including the SPF and its components or inputs (i.e. SDMs, policies, goals, UI, etc) are undergoing continuous validation and are subject to change. **The results and screenshots in this deliverable are provided solely to demonstrate that the SPF has been successfully developed and integrated into the SLNAE**.

Following the validation process, in which CSs and SHs will certify the behavior of the SLNAE modules, the final version of the tool will be deployed. This process will be expedited depending on the CS through interactive workshop settings with SHs. For the front runners, the SPF will be ready by August 2024 (M36), including the Inkomati CS. For the followers, it will be ready by December 2024 (M40).

The final version of the SLNAE is expected to be ready by February 2025 (M42) and will be reported in D4.5 *Final version of the self-assessment nexus engine with the corresponding*

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validation (M42). This final version will include additional secondary functionalities that are not necessary for the success of the upcoming Workshops (WSs).

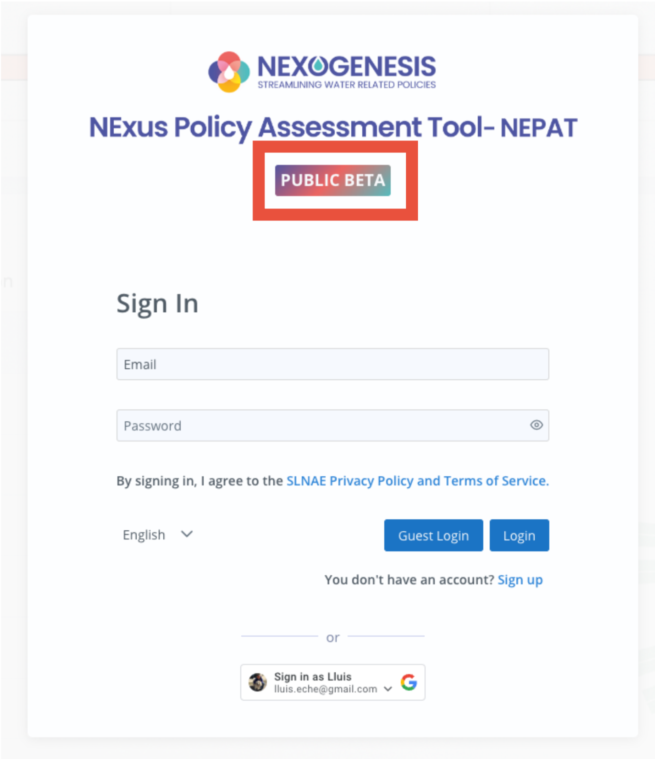

Figure 3. SLNAE UI. Beta version warning.

1.2. Links to the ICT4WATER Cluster

WP4 is considered the 'digital' WP in the Nexogenesis project. Thus, it is the natural link between the project and the ICT4WATER Cluster[1].

The outcomes of the task T4.3 are specially linked to the ICT4WATER Digital Water Action Plan and its 'Intelligent and smart systems', 'Actor engagement and co-creation' and 'Policies' Action Groups[2].

Particularly, this deliverable and the digital services developed under T4.3 contribute to[3]:

- The 'Intelligent and smart systems' action 5 activities 1 & 2: Uncertainty is taken into account in the integrated complexity science models.
- The 'Actor engagement and co-creation' action 1 activity 1: A public online tool (the SLNAE) is developed.

[1] https://ict4water.eu/
[2] https://ict4water.eu/action-group-data-sharing/
[3] https://ict4water.eu/wp-content/uploads/2023/06/Update-Digital-Water-Action-Plan-V7.pdf

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- The 'Actor engagement and co-creation' action 2 activities 1 & 2: Stakeholders from all nexus sectors are taken into account during the Nexogenesis co-creation process for the SLNAE design.
- The 'Policies' action 5 activity 1: The SLNAE tool enables policy co-creation.
- The 'Policies' action 6 activity 2: The SLNAE tool enables improved management of governance complexity including uncertainty and other factors.

1.3. NEPAT: a new name for the SLNAE

During the initial period of the project, it was necessary to explain the definition and meaning of the SLNAE to non-technical audiences (e.g. stakeholders) on multiple occasions. The term "Self-Learning" is a technical concept related to AI and ML algorithms involved in its development, which can be difficult to understand and may generate confusion. Additionally, the acronym SLNAE and the full name are not easy to pronounce. Therefore, it was decided with the NXG consortium that a new name was needed.

WP4 led the initiative to define a new name that would be self-explanatory and avoid technical jargon, while incorporating Nexogenesis-related concepts such as "policy assessment" or "impact." Several options were proposed under the cocreation framework and put to a vote, and eventually, the name "Nexogenesis - Nexus Policy Assessment Tool (NEPAT)" was selected as the best option. The new name is simpler, easier to pronounce, and more reflective of the tool's and project's purpose. In order to be consistent with the GA and other official documentation, both names are valid to refer to the SLNAE.

Thus, the SLNAE tool is referred to as either SLNAE or NEPAT.

1.4. Document structure

The document is structured as follows: Section 2 summarizes the integration of policies, goals and the Nexus footprint index into the SDMSs (by WP3). Next, Section 3 describes the Simulation Policy Framework, composed by the Data Manager, the SDM Translator, the SDM Manager, the SPF Core Service and the SPF Web Service API. Finally, section 4 ends with the conclusions and next steps.

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2. Policies, goals and the WEFE footprint integration

For each of the five NXG's CSs, a number of policies and goals, and the WEFE footprint, have been integrated into the SDMs by WP3. This section briefly describes this process, since it conforms the basis for the task T4.3 and the Simulation Policy Framework.

2.1. Policies integration

Different policies, based on real-life nexus-related policies, have been implemented in the SDMs in order to assess their impact on the entire WEFE nexus. Each case study has a different number of policies (Annexes I to V), according to the policies identified in collaboration with case study leaders and in SH workshops. However, implemented policies cover most, if not all, WEFE nexus sectors. Due to the interconnections between the sectors in the models, implementation of a policy will have impacts beyond just the sector for which it was developed.

The baseline SDM (i.e. without policy implementation, the reference scenario) is amended to allow for the assessment of the potential impact of a policy action. In the SDM, this takes the form of a 'policy variable' that, upon activation, acts to alter the value(s) of the baseline variables.

Technically, in the SDMs, each policy is first allocated a 'switch' variable. If the switch is turned off, then the corresponding policy is inactive (i.e. the baseline or reference scenario). Once the switch is turned on, the policy becomes active, affecting model behaviour. This is done through another variable that codes the policy objectives in the SDM framework. For example, once a switch is active, the corresponding policy variable may act to reduce the baseline per-capita water demand by 10% by 2035. Or in another case, activating a policy switch may cause the area of farmland to be decreased by a given percentage, while the area of protected lands increases by the same percentage. Taking the case of the farmland decreasing, in some case studies, this may subsequently lead to changes in crop production, irrigated water demand, energy demand, greenhouse gas emissions, carbon sequestration, and biodiversity indices, showing how connected the WEFE sectors are in the models. Policies in the SDMs can be implemented either one-at-a-time, or in combination as a series of 'policy packages'. Again, due to the interconnected nature of variables in the SDMs, implementing policies as packages will lead to complex behaviour patterns that may differ from implementing each policy in isolation.

For example, in the Inkomati CS (Annex V), policies 5 and 6 aim to reduce domestic water demand by a certain percentage relative to a reference year. Upon activation, these policies take the reference domestic water demand and reduce it by the specified percentage. Due to

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interrelationships within the nexus SDMs, such actions may also have knock-on impacts, such as reducing nitrogen runoff from domestic water supply, or reducing the energy demand for water supply. These effects are implemented in the Inkomati SDM, specifically within the water module (Figure 4). Here, it can be seen how policies 5 and 6, implemented through the switch components P05 and P06 (highlighted in blue in Figure 4), are linked to the domestic water withdrawal and domestic nitrogen load. The effects of these policies are given by the variables *P05 water demand reduction*, *P06 water demand reduction*, *P05 N load reduction* and *P06 N load reduction*.

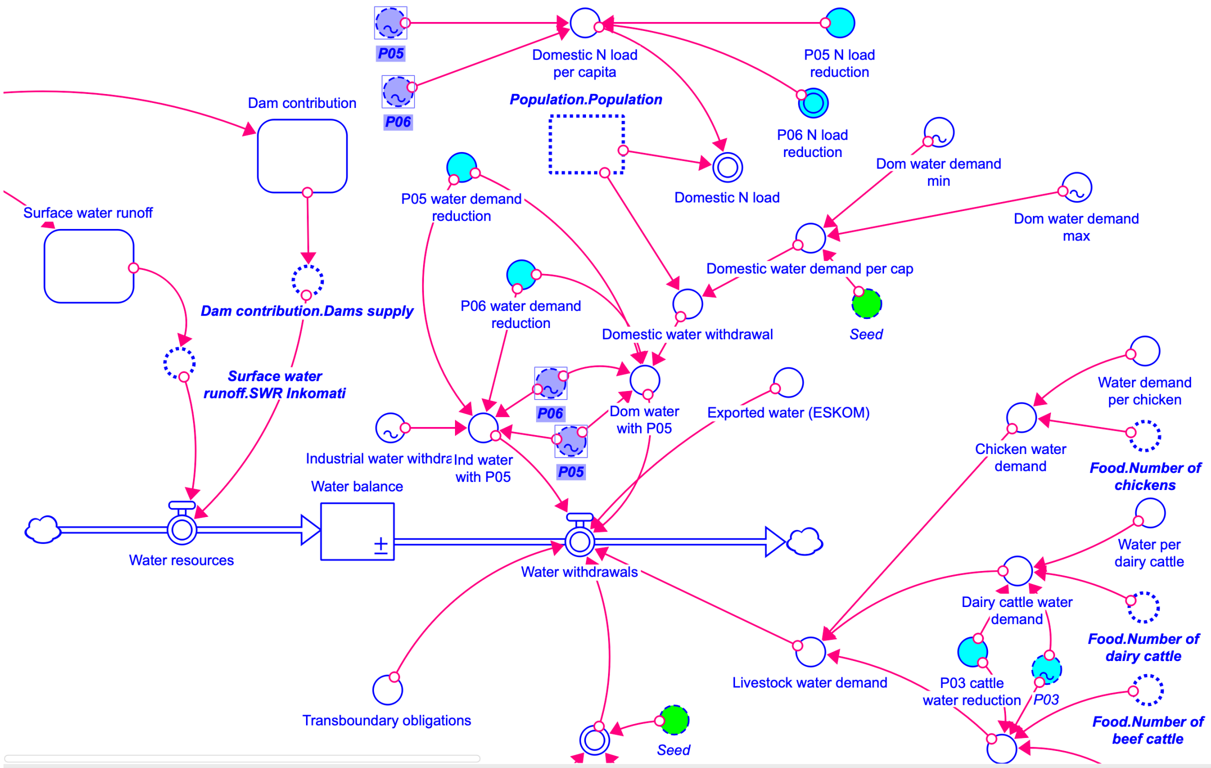

Figure 4. Inkomati SDM. Water module.

2.2. Goals integration

Different goals, linked to the CS's characteristics and objectives, have been specified in order to provide a measure of the policies and policy packages' performance. Each case study has a different number of goals (Annexes VI to X), according to the goals identified with each case study leader.

For each goal, a specific indicator has been included in the SDM. For example, in the Inkomati CS (Annex X), goal 13 is aimed to increase the subsistence farming production. In order to evaluate this goal, the *Rainfed Subsistence Area* indicator has been implemented in the SDM, in the Land Use module (Figure 5).

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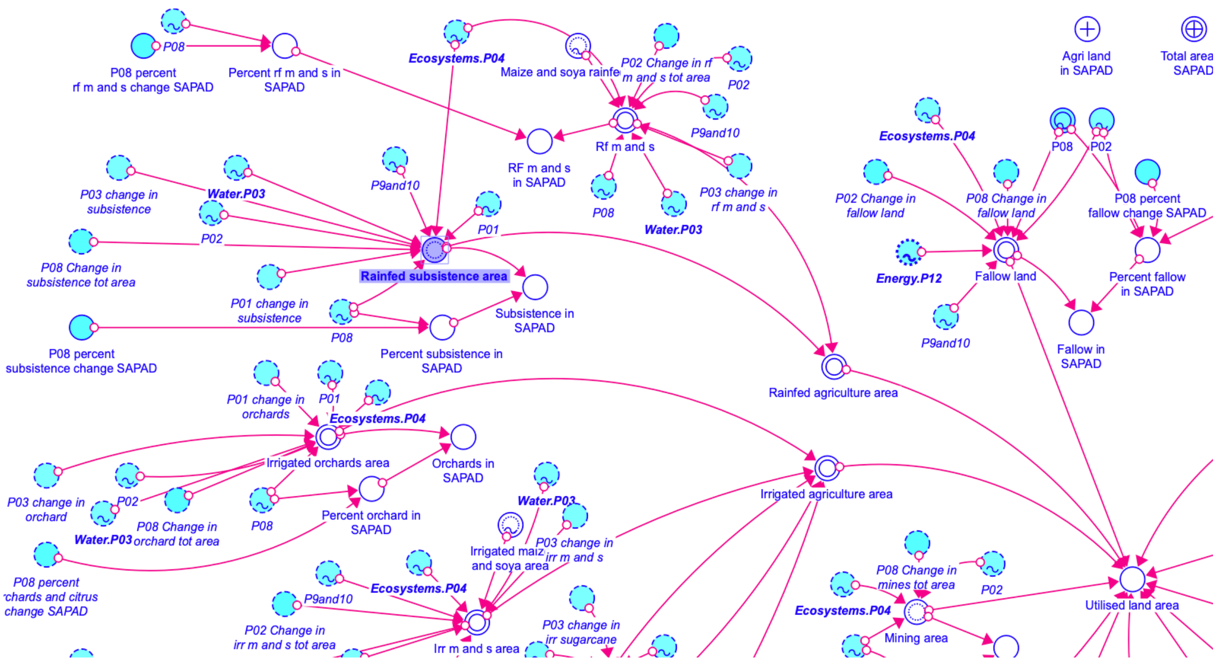

Figure 5. Inkomati SDM. Land Use module.

2.3. WEFE footprint integration

The WEFE footprint index is also integrated into the NEPAT through the CSs' SDMs. Each SDMs includes a separated module implementing the index, encompassing all its pillars and indicators. Figure 6 – Left represents the top layer of the Inkomati SDM, along with its submodules. The WEFE index module is highlighted in orange. Figure 6 – Right shows the WEFE Index module itself, including all the required nexus indicators.

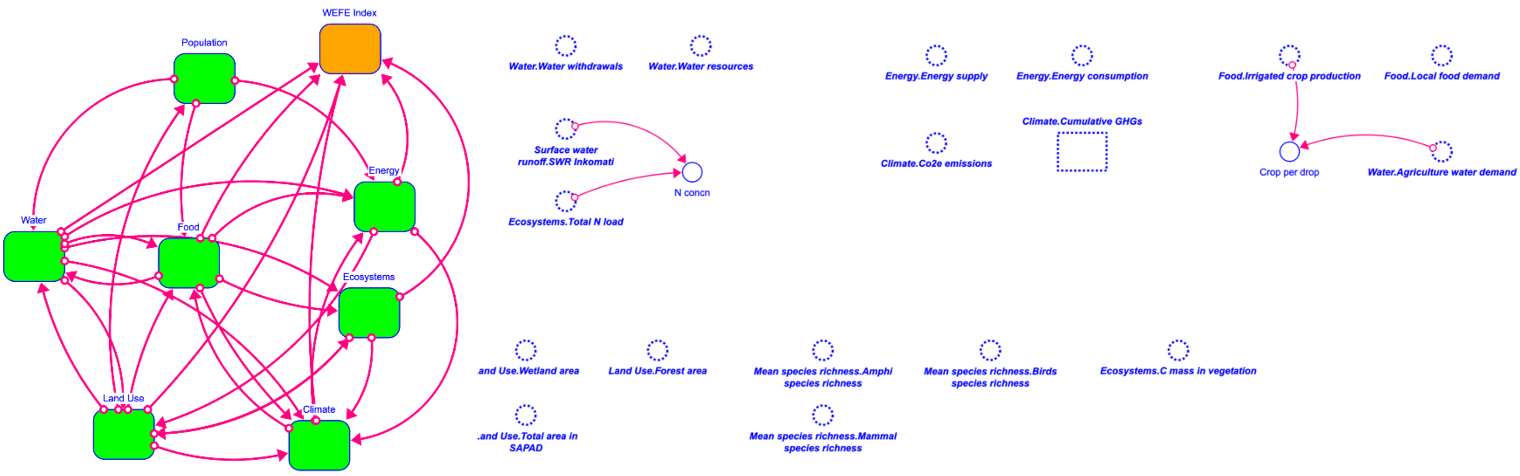

Figure 6. Left: Inkomati SDM. Right: WEFE Index module

As of the writing of this document, the WEFE Footprint Index is still under development by WP3 in Task T3.5 *WEFE Nexus Footprint*. Therefore, modifications are expected. The final

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version will be reported in deliverable D3.7 *Final report on the WEFE Nexus Index methodology and visualization* (M36).

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3. Simulation Policy Framework

The Simulation Policy Framework is a key module of NEPAT, responsible for integrating complexity science models (i.e., the SDMs), policies, and nexus goals of each CS, along with the Nexus Footprint Index. Indirectly, the integration of the complexity science models includes the integration of the bio-physical and socio-economic data generated by the WP2 models behind.

This integration results in a module that can be used to simulate the impact of a policy or a policy package across the nexus and assess its performance against the goals of the CSs or the Nexus Footprint Index. Several functionalities are available depending on the needs and type of user. For instance, users can run multiple simulations of a given SDM to analyze parametric model uncertainty or visualize the affected nexus components based on a selected policy package.

This module is composed by different components, such as the Data Manager, the SDM Translator, the SDM Manager, the SPF Core Service or the SPF Web Service API (part of the NEPAT Web Service API). The SPF Core Service is a logic entity responsible of the SPF management, while the SPF Web Service is the user's entry point which can be used directly, via HTTP protocol requests, or through the NEPAT UI, to run a nexus simulation.

The integration of all the components previously mentioned has been implemented as a pipeline process, as it can be seen in Figure 7.

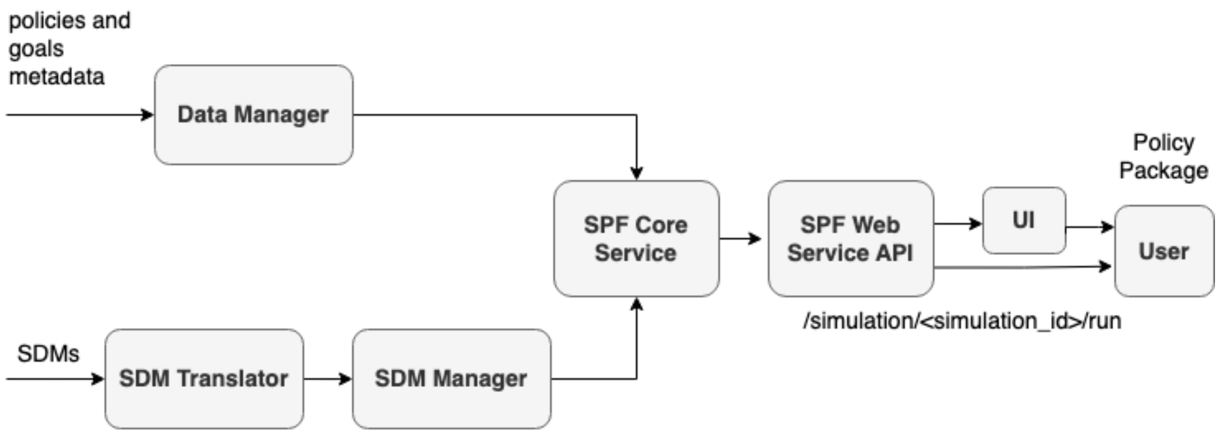

Figure 7. Simulation policy framework pipeline

The framework begins with the Data Manager and the SDM Translator components. The Data Manager is in charge of loading the metadata for policies and goals, received as input from WP1 and WP5 (along with CSs and SHs), and making them available for its usage. Additionally, it is responsible for providing this data for storage in the Nexogenesis Semantic

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Repository (see D4.2 *Data Lake for Data sharing*). In the repository, the data is persisted in RDF (Resource Description Framework) format, a standard protocol for semantic data.

The SDM Translator receives as input the SDMs (from WP3), in STELLA format, and translates them into Python, integrating them into the NEPAT system and ultimately making them available for use in the NEPAT. During this phase, the logic and rules of SDMs can be adjusted to integrate additional events that may influence and change the baseline behavior of the reference scenarios, which are defined by the combination of RCP and SSP. These events are formalized using JSON rules, with policies being a specific type of event. While policies are implemented directly in the SDMs, they can also be integrated through the SPF. This SPF feature also allows for the inclusion of additional uncertainty factors, such as climate events. However, simulating these additional factors requires further research and the expansion of data (WP2) and SDMs (WP3) to account for these events, which were not initially considered in in either WP2 or WP3. In simpler terms, while the tool is capable of incorporating these effects, it would require additional data and further research into their complex interlinkages and impacts, as these were not originally included in the project plan.

Four SDMs (two in case of the Adige CS) are provided for each CS, corresponding to the combinations of Representative Concentration Pathways (RCPs) 2.6 and 8.5 with Shared Socioeconomic Pathways (SSPs) 2 and 4 (i.e. RCP2.6 & SSP2, RCP2.6 & SSP 4, RCP8.5 & SSP2 and RCP8.5 & SSP4). Each combination defines a different reference scenario and enables scenario uncertainty analysis (i.e. assessing the difference between future projections of a system development).

Furthermore, SDMs also include parametric uncertainty. Parametric uncertainty involves exploring the uncertainty in a given model variable. Input SDM variables may be estimated from different external models, and provided via WP2 data, often give a range of values. As a result, several variables may be affected. The SDM translation process also includes this uncertainty making it available for user analysis. See deliverable D3.6 *Sensitivity/Uncertainty Analysis Report* for further details on SDMs uncertainty.

Once translated, these Python SDMs are then fed to the SDM Manager, which use them to run simulations based on user requests. A user request must specify the CS, the reference scenario, and the policy package to be executed. As a result, the SPF generates a response with all the nexus variables available in the SDMs. The values of these variables depend on the applied policy package, which will determine the nexus impact.

Finally, the pipeline process concludes with the UI, that enables users to run simulations (by configuring a policy package) and analyse their results across all the nexus sectors.

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3.1. SDMs Integration

In this section, the integration of SDMs into the simulation framework is presented. WP2 and WP3 have provided data and SDMs for each RCP and SSP covered combination, utilizing the STELLA language. To incorporate these SDMs into the SPF, two key components have been employed: the SDM Translator and the SDM Manager.

The SDM Translator converts the SDMs from STELLA into Python, allowing them to be executed by the NEPAT backend. Once translated, the SDM Manager takes charge of running these SDMs. It selects the appropriate translated SDM script, runs it with the specified policies, and delivers the results to the Web Service API for return to the user.

The following subsections detail the functionality and operation of each component.

3.1.1. SDM Translator

The translation process of the SDMs is done by a set of steps seen in Figure 8, starting with an equation file generated from exporting the STELLA model, and some CS specific metadata. The whole process is overseen by the "Conversion script manager", which implements the flow to run all the steps.

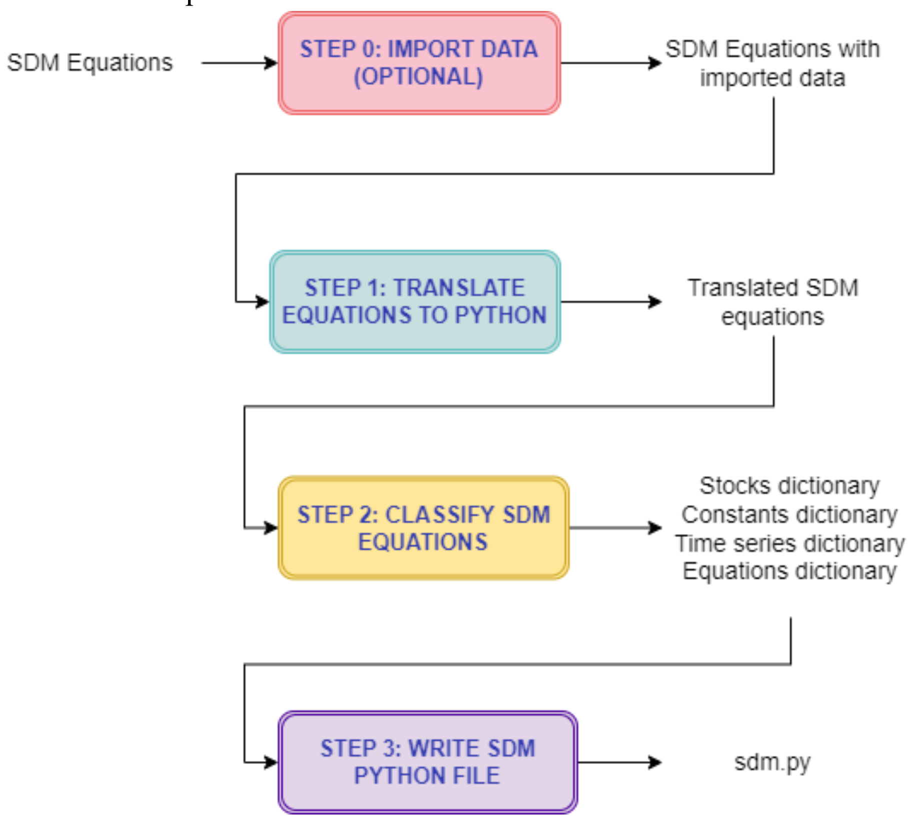

Figure 8. SDM translator schema. Conversion script.

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3.1.1.1. Step 0: data import

In some CSs, the ISEE system's import feature is used, and some of the GRAPH(TIME) variable values (defining the SDM inputs) are defined in an Excel file to be imported. In those cases, the "Conversion script manager" performs the following steps:

- Loads the Excel file with the variables to import.
- Iterates over each line of the SDM equations file and adds the corresponding GRAPH(TIME) line with the points of the variables found in the Excel file.

This results in a new SDM equations file with the values of the imported variables incorporated.

3.1.1.2. Step 1: translation

Step 1 is where the actual translation from STELLA to Python is performed. This step is modelled as a dual-layered approach, performing both a lexical analysis and a syntactical analysis to produce accurate translations that preserve the logical structure and functionality of the original code.

Lexical analysis ensures that individual tokens, such as keywords, operators and identifiers, are correctly identified and covered. While STELLA allows identifiers to have any type of characters, Python is much more restrictive, allowing only letters, numbers and underscores. In this phase, special characters such as quotes, periods, parentheses, and others are either removed from variable names or transformed into underscores for compatibility and consistency. Words like the scenario name (RCPXXSSPX) are also removed from the variable names to ensure that all SDMs indicators have the same names and simplify the evaluation of nexus goals and indicators in further steps. STELLA operators like MIN, MAX, SUM, RANDOM, UNIFORM and TRIANGULAR are transformed to their equivalent python representations. Other operators like "//", which corresponds to the safe division in STELLA, or the PREVIOUS operator, which retrieves the previous value of a variable, had to be implemented because there is no equivalent in Python.

Syntactic analysis, on the other hand, focuses on the structure and rules governing the source code to produce a syntactically correct translation in the target programming language. During this step, the following transformations are made to the STELLA equations:

- Constant expressions such as ': c var = (15/100)' are evaluated and transformed into expressions like ': c var = 0.15'.
- Random expressions are transformed into their python equivalents. In STELLA, these expressions receive the seed as a parameter, whereas in Python, the seed must be set only once using random.seed(), and thus the seed parameter is removed from individual random function calls.
- Conditional statements, which are defined as IF THEN ELSE statements, are added missing spaces and transformed into Python equivalent expressions. PLY's yacc[4]

[4] https://www.dabeaz.com/ply/ply.html

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module is used to translate the conditional statements, since it is the only way to resolve the ambiguities inherent in their structure.

3.1.1.3. Step 2: equations classification

The translated equation file is produced in step 1. Using this file as input, step 2 generates distinct data structures for each variable type:

- Region constant: stores the values of all the constant variables of the SDM.
- Region time: contains all the time series variables, which are the ones defined as GRAPH(TIME) in the original SDM.
- Region stock equations: this data structure holds all equations corresponding to stock equations. Since stocks rely on their previous value to compute their current step value, an extra structure is created for them, including their initial values.
- Region equations: contains all the rest of equations found in the translated file.

During this step, policies, which may have been modelled as either constants or time series, are identified and unset, with their values being set to 0. This defines the reference scenario, with no policies applied. Additionally, a file listing the variables directly affected by the policies is generated.

3.1.1.4. Step 3: python file generation

With all the equations translated and classified, the next step is to generate the Python SDM. Considering the uncertainty incorporated in the SDMs, two translation scenarios are generated:

- SDM original: This Python file contains the ordered equations and mirrors the behaviour of the original STELLA SDM, including data stochasticity.
- SDM average: This script represents an average scenario with no data uncertainty. All random equations are transformed into averages. This version is used for deterministic executions.

To ensure the accuracy of the translations, a validation process is conducted after the translation. The original SDM translation is executed and compared against values directly derived from the STELLA model's run results.

3.1.2. SDM Manager

During the translation step outlined in the previous section, a Python translation is generated for each CS reference scenario pair. The SDM Manager assumes responsibility for handling these translations and encompasses various tasks associated with them. Within the SPF pipeline, this component is pivotal as it executes the SDMs according to specified configurations and subsequently provides the result.

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To effectively execute a simulation, the SDM Manager requires at least the following configuration parameters:

- Policies: a list of policies to activate during the simulation execution. Depending on the CS these may involve specifying the policy configuration or policy application year apart from the variable corresponding to the policy in the SDM.
- SDM identifier: the id of the specific System Dynamics Model to be executed, representing the CS and the reference scenario. This identifier allows the SDM Manager to select and run the appropriate model.
- Random mode: A parameter that determines the translated scenario to run (i.e. SDM original or SDM average).

By configuring these parameters, the SDM Manager can accurately run simulations, apply the necessary policies, manage variable outputs, and handle random elements appropriately (Figure 9).

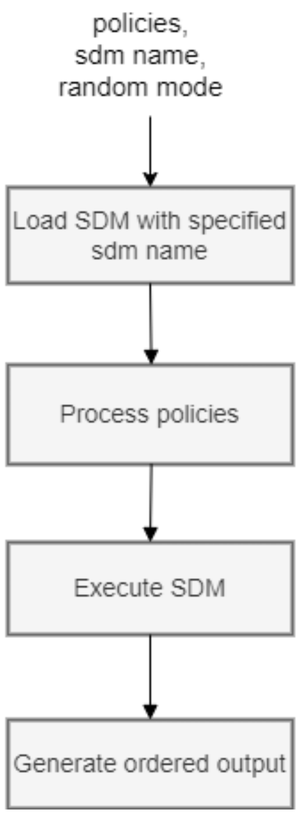

Figure 9. SDM Manager steps to run a simulation.

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3.2. Policies and Goals Integration

As mentioned in Section 2, WP3 has integrated the policies, goals and nexus indicators (proposed by WP1 and WP5 along with the CSs and SHs) into the SDM. Additionally, WP1 and WP5 also provided the metadata for the policies and goals (Annexes I to X).

The Data Manager is responsible for loading this metadata into the NEPAT, which will then be used by other modules, such as the Web Service API or the DSS (see deliverable D4.4 *Core module of the self-learning nexus engine*). This step ensures that all relevant information is accurately captured and readily accessible for simulations, analyses, and decision-making processes. Once loaded, these objects enable seamless integration and interaction between different components of the system, facilitating efficient data management and operational coherence.

The integration with the Web Service API involves utilizing the loaded objects to populate the database with policies and goals. The Web Service API accesses these Python objects to create corresponding entries in the database, ensuring that the data is accurately represented and readily available for further use. These database entries are then accessed and displayed in the UI, providing users with an up-to-date and consistent view of the policies and goals within the system.

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3.3. Web Service API

The SPF Web service API serves as a bridge between the user, which may access it directly via HTTP requests or via the UI, and the rest of components in the SPF (Figure 7). Within the detailed pipeline, it offers the /simulations/run endpoint, which allows for the execution of simulations for any CS-Scenario combinations using a predefined policy package.

The SPF Web service API, as part of the global NEPAT Web service API, implements the Representational State Transfer (REST) [1] software architectural style.

The details of the /simulations/run endpoint, including the HTTP available methods, the required request parameters (in JSON format) and the response structure (in JSON format) are presented in Table 1. Currently, only the English language is supported, but other languages will be integrated by the final version of the NEPAT tool.

Table 1. Simulation run endpoint

<table>
<tr><td>Location</td><td colspan="3">/simulations/{id}/run</td></tr>
<tr><td>Methods</td><td colspan="3">POST</td></tr>
<tr><td rowspan="3">Params</td><td>Name</td><td>Type</td><td>Description</td></tr>
<tr><td>id</td><td>String</td><td>Id of the simulation to run.</td></tr>
<tr><td>baseline</td><td>Boolean</td><td>Whether to return the results for the baseline too.</td></tr>
<tr><td>Headers</td><td colspan="3">Accept-Language: [en]
Authorization: Bearer <token></td></tr>
<tr><td>Body</td><td colspan="3">[
  {
    "policy_id": 0,
    "year": 0,
    "value": 0
  },
…
]</td></tr>
<tr><td rowspan="2">Response</td><td colspan="3">Message</td></tr>
<tr><td colspan="3">[200, OK]:
{
  "var_tree_values": {},
  "footprint": 0,
  "policy_goals_targets": {}
}

[422, Validation Error]</td></tr>
</table>

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	{
	"detail": [
	{
	"loc": [
	"string",
	0
	],
	"msg": "string",
	"type": "string"
	}
	]
	}

	Cookies
	-
Description	This endpoint runs a simulation using the provided ID and the specified policy package. If the baseline flag is set, it returns the results for both the baseline/reference scenario and the scenario with the specified policy package applied.

The authentication token can be obtained from the /auth/login endpoint of the NEPAT Web Service API, which will be detailed in deliverable D4.5 *Final version of the self-assessment nexus engine with the corresponding validation* (M42).

Following this specification (Table 1), any user can run a simulation by implementing the required HTTP request. There exist several mechanisms to do this. Specifically, the NEPAT provides an online tool for interaction via its public Web Service API documentation (https://nepat-dev.nexogenesis.eu/api/docs). An example is detailed below.

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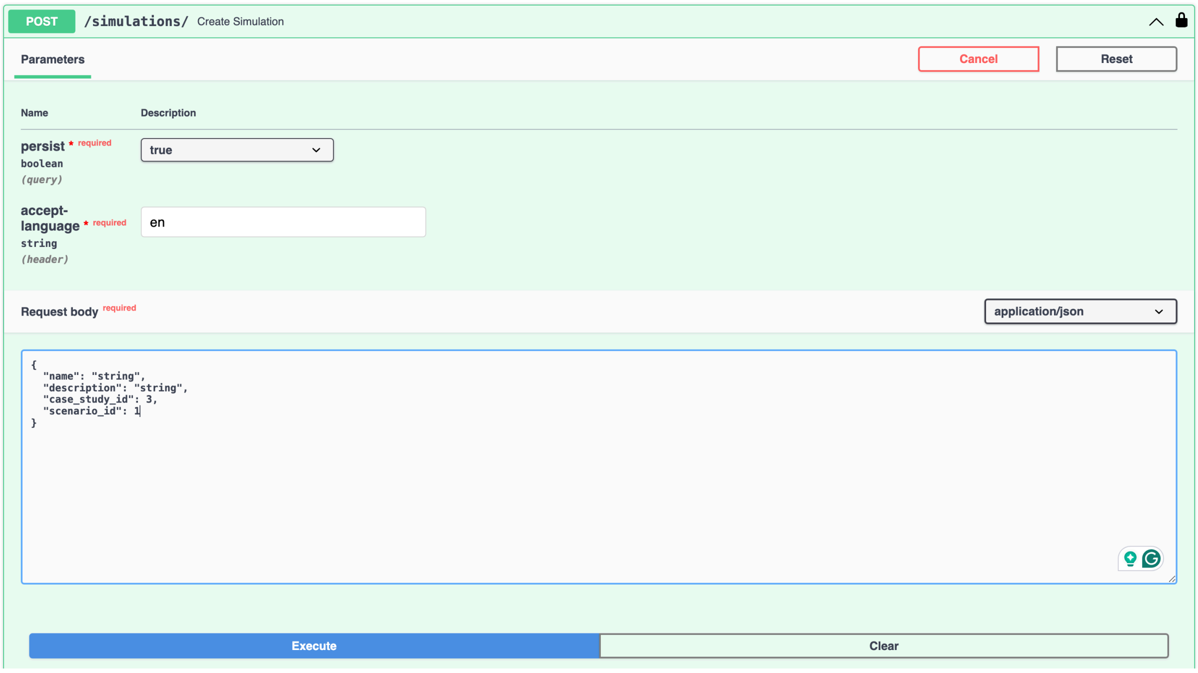

Figure 10. Online NEPAT Web Service API documentation. /simulations/ endpoint. POST HTTP method request specification.

First, a simulation must be created through the /simulations/ endpoint (Figure 10). This requires a POST request where the necessary parameters are specified, such as a simulation name, description, and the CS and reference scenario IDs. If the request is successful, the simulation is created, and a simulation ID is generated. The user receives the response in JSON format (Figure 11). In case of an error, it is specified in the response as well. Before performing this step, an authentication token is required, which can be obtained via the /auth/login endpoint of the same Web Service, as mentioned previously.

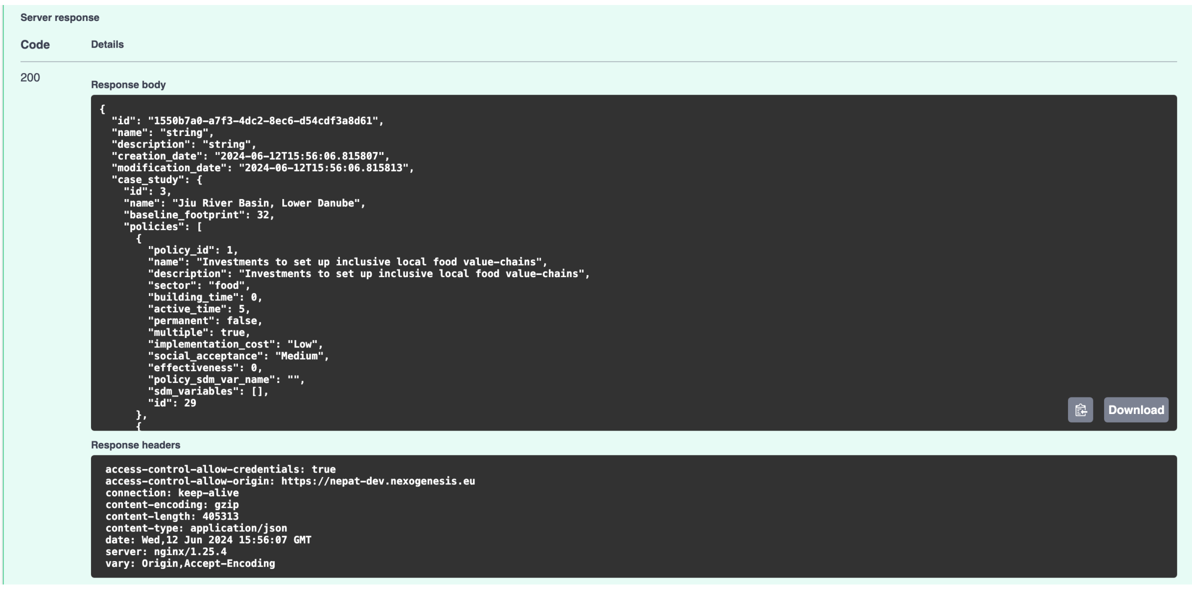

Figure 11. Online NEPAT Web Service API documentation. /simulations/ endpoint. POST HTTP method response specification.

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Once the simulation is created, the corresponding baseline reference scenario is executed through the SDM Manager. Therefore, the HTTP response provides several pieces of information, such as the available policies that can be applied (linked to the selected CS), the goals' metadata and their achievement, and all the nexus variable values. All the nexus data correspond to the reference scenario with no policies applied.

The user can now start testing different policy packages through the /simulations/run endpoint (Figure 12). This requires a POST request, where the simulation ID is provided along with the list of policies to be applied and other parameters. If the request is successful, the simulation is run, triggering the SDM Manager again to execute the corresponding SDM with the specified policies.

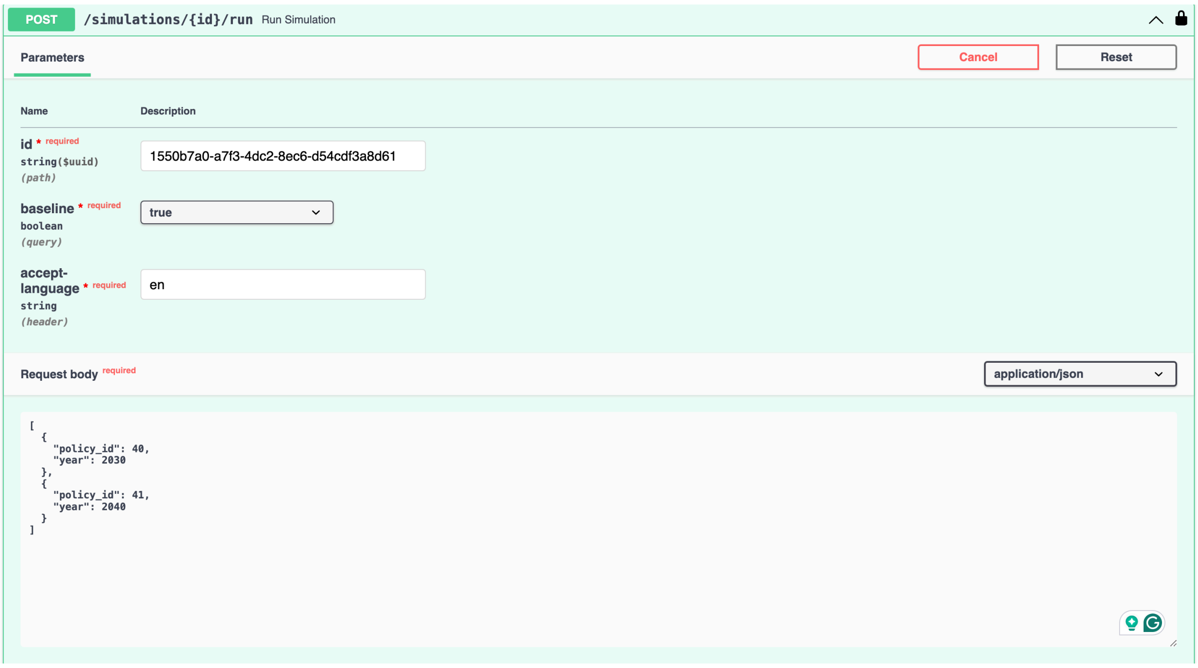

Figure 12. Online NEPAT Web Service API documentation. /simulations/run endpoint. POST HTTP method request specification.

The user then receives the request response in JSON format (Figure 13). The HTTP response provides several pieces of information, such as the achievement of goals, all corresponding to the implemented policy scenario.

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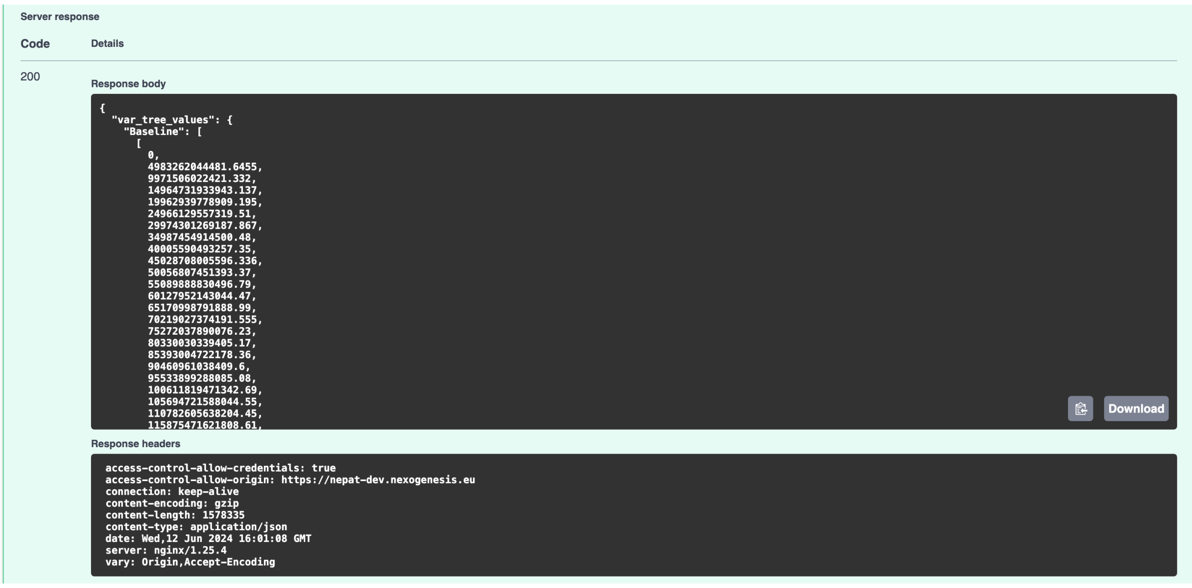

Figure 13. Online NEPAT Web Service API documentation. /simulations/run endpoint. POST HTTP method response specification.

The NEPAT Web Service API can be found in the following urls https://nepat-dev.nexogenesis.eu/api/ and https://slnae-dev.nexogenesis.eu/api/

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3.4. Graphical User Interface

Although users can run simulations by directly accessing the SPF Web Service API, as demonstrated in the previous section, this process requires advanced IT knowledge and tools, which are not common among NEPAT's SHs.

Therefore, NEPAT also provides a powerful Graphical User Interface (UI) that allows users to explore the nexus and analyze the impact of custom policy packages, among other functionalities. The UI integrates with the SPF Web Service API and all other endpoints in the NEPAT Web Service API, following the previous specifications, to provide its functionalities.

Specifically for the SPF module, different views have been developed. First, the main view, which is the first view the user accesses after creating a simulation. In this view, the top component is the policy package section, highlighted in red in Figure 14. Initially, this component is empty, as no policies have been applied yet, corresponding to the reference scenario. This component remains visible across all NEPAT sections to remind the user which policies are being applied and to indicate what all the displayed nexus values correspond to.

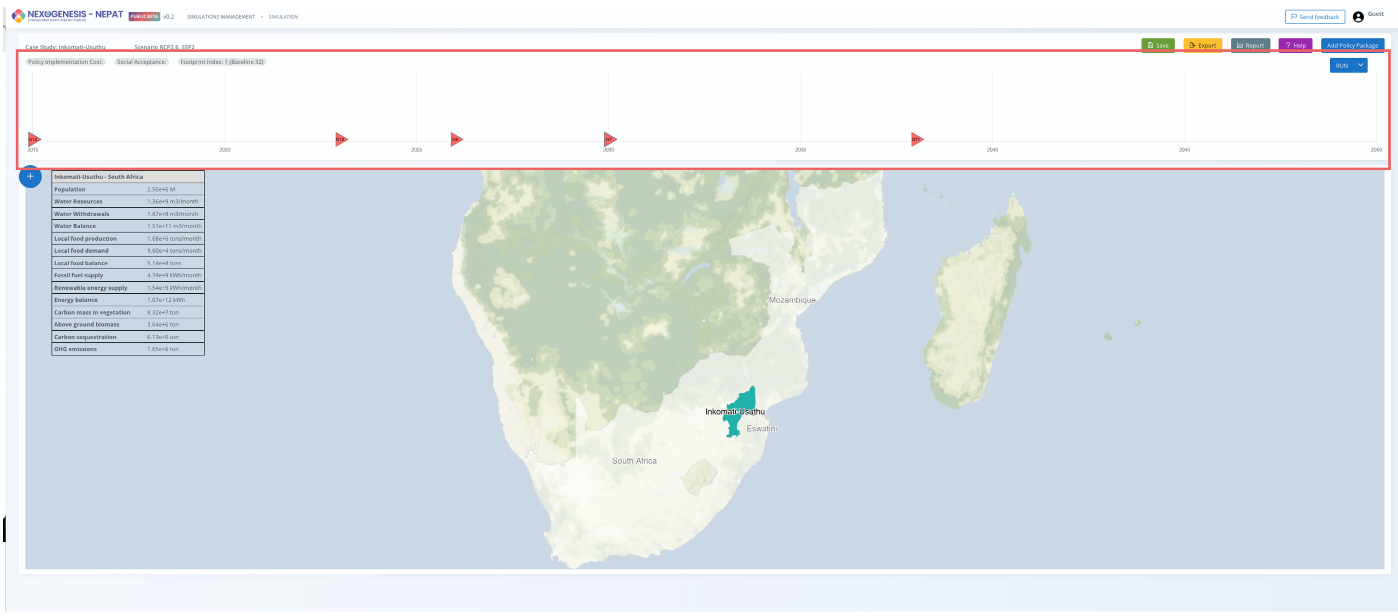

Figure 14. NEPAT main view for the Inkomati CS

The policies view is another important NEPAT functionality linked to the SPF module (Figure 15). In this view, all available policies are listed and described. Additionally, the graphic on the right, which represents the nexus (i.e., all the SDM variables and their interlinkages and dependencies), helps identify the policies' impact on the nexus. It highlights the nexus variables affected by the selected policy.

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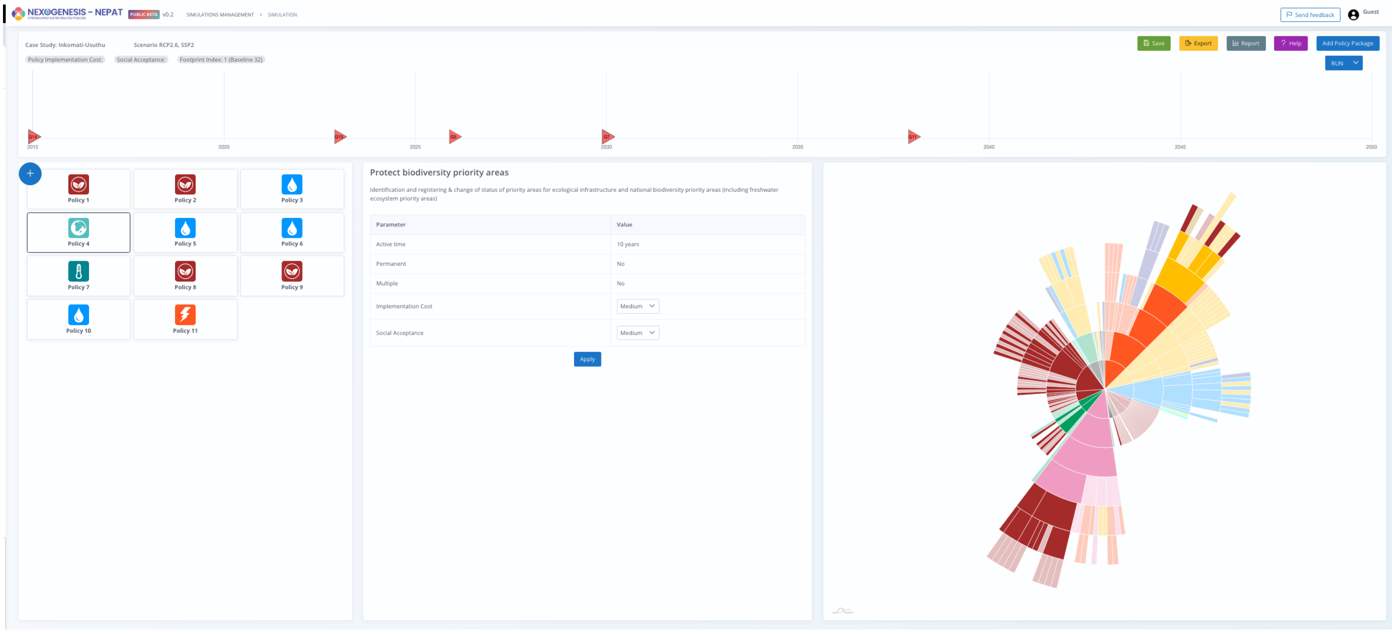

Figure 15. NEPAT policies view for the Inkomati CS

Through this view, the user can configure the policy package by applying policies (Figure 16). Depending on the policy, different configurations can be selected. Additionally, depending on the CS, the user may decide the year in which the policy will be applied.

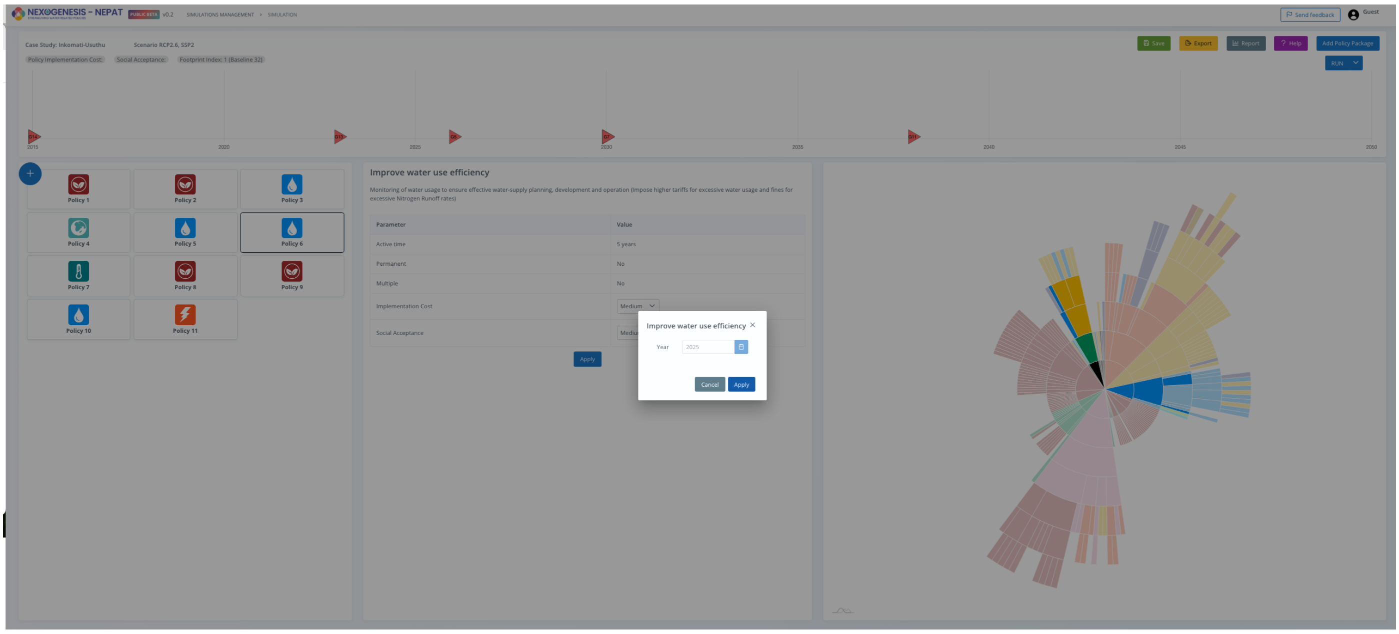

Figure 16. NEPAT policies view for the Inkomati CS. Confirmation pop-up for policy implementation.

Once applied, the policy is introduced into the policy package section (Figure 17). The user can then run the simulation with this new policy package by clicking the RUN button and ultimately analyze its impact.

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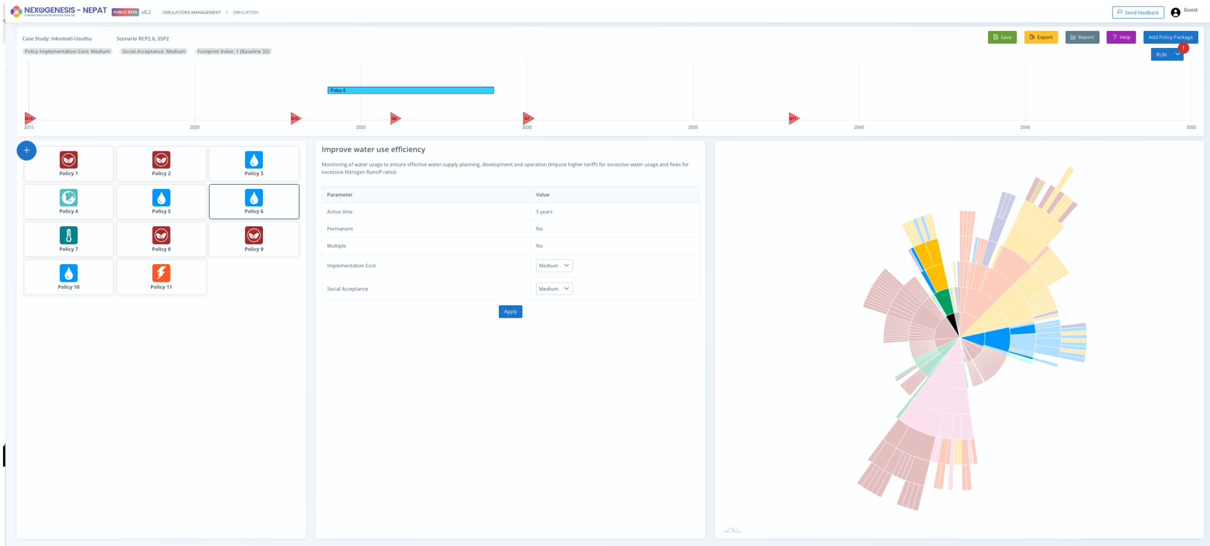

Figure 17. NEPAT policies view for the Inkomati CS. A policy has been included into the policy package component.

The NEPAT UI can be found in the following urls https://slnae-dev.nexogenesis.eu and https://slnae-dev.nexogenesis.eu

Additional views and functionalities will be reported in D4.5 *Final version of the self-assessment nexus engine with the corresponding validation* (M42).

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4. Conclusions

The **Simulation Policy Framework** has been successfully implemented, deployed and integrated into the SLNAE platform, achieving the main objective of task T4.3 and one of the key stages of WP4 in the Nexogenesis project.

Through the SPF, SLNAE users can now interact with the nexus components, and evaluate and visualize the impact of different customized policy packages for each of the 5 NXG CSs. On this basis, additional SLNAE functionalities can be built, such as the Decision Support System, or the comparison view in the UI.

It is composed by different components, including the Data Manager, the SDM Translator, the SDM Manager, the SPF Core Service or the SPF Web Service API. All of these components are detailed in this document.

The current version of the Simulation Policy Framework is embedded in the public release of the SLNAE at the following urls: https://slnae-dev.nexogenesis.eu or https://nepat-dev.nexogenesis.eu. The SPF Web Service API is available at the following urls: https://nepat-dev.nexogenesis.eu/api/ or https://slnae-dev.nexogenesis.eu/api/

Since the SFP inputs (i.e. the SDMs, the policies, the goals or the Nexus footprint) are under constant validation, the current published version of the SPF is designated as a Beta version and is subject to change. The SPF will be ready by August 2024 (M36) for the frontrunners CS (including the Inkomati CS), and for the followers CSs, it will be ready by December 2024 (M40).

The final version of the SLNAE is expected to be ready by February 2025 (M42) and will be reported in D4.5 *Final version of the self-assessment nexus engine with the corresponding validation* (M42).

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5. References

[1] Fielding, R. T. (2000). CHAPTER 5 Representational State Transfer (REST). *Architectural styles and the design of network-based software architectures*. University of California, Irvine.

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Annexes

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Annex I: CS1 policies (Nestos River Basin)

N of policy	ID	Scale	Sector	Short name	Long description	SDM variable	Can not be applied with	Starting year	Ending year
1.1	1	GR	Water			BG___Irrigation_technology__Switch_irrigation_technology_policy		01/01/2015	01/12/2050
1.2	2	Basin	Water			GR___Irrigation_technology__Switch_irrigation_technology_policy		01/01/2015	01/12/2050
2	3	Basin	Water			Irrigation_water_transport_system_loss_coefficient__Open_canals_vs_closed_pipeline_existence		01/01/2025	01/12/2050
3.1	4	GR	Water			BG___Nitrogen_crop_application__Switch_nitrogen_reduction_policy		01/01/2025	01/12/2050
3.2	5	Basin	Water			GR___Nitrogen_crop_application__Switch_nitrogen_reduction_policy		01/01/2025	01/12/2050
4	6	GR	Water			GR___Cultivation_of_lesser_water_intensive_crops__Switch_water_intensive_crops_decrease_policy		01/01/2025	01/12/2050
5	7	BG	Water			BG___Cultivation_of_lesser_water_intensive_crops__S		01/01/2025	01/12/2050

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						witch_water_intensive_crops_decrease_policy			
6	8	Basin	Water			Livestock_water_infrastructure__Switch_livestock_WD_decrease_through_modernisation_of_water_infrastructure_policy		01/01/2030	01/12/2050
7	9	Basin	Ecosystem			Reforestration__Switch_forest_land_increase_policy		01/01/2030	01/12/2050
8	10	GR	Food			GR___Dynamic_crops__Switch_dynamic_crops_increase_policy		01/01/2030	01/12/2050
9	11	GR	Energy			GR___Energy_policy__Switch_conventional_energy_generation_decrease_policy		01/01/2020	01/12/2050
10	12	BG	Energy			BG___Energy_policy__Switch_conventional_energy_generation_decrease_policy		01/01/2020	01/12/2050

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Annex II: CS2 policies (Lielupe River Basin)

N of policy	ID	Scale	Sector	Short name	Long description	SDM variable	Can not be applied with	Starting year	Ending year
1.1	1	Latvia	Nature based solutions	Fraction of land with nutrient treatment in LV: riparian buffers	Extension of use of riparian buffers as a nutrient treatment alternative. The value represents the fraction of land (in Latvia) with nutrient treatment using riparian buffers.	Nature_based_solutions_LV__policy_switch___fraction_of_land_with_riparian_buffers		01/01/2015	01/12/2049
1.2	2	Lithuania	Nature based solutions	Fraction of land with nutrient treatment LT: riparian buffers	Extension of use of riparian buffers as a nutrient treatment alternative. The value represents the fraction of land (in Lithuania) with nutrient treatment using riparian buffers.	Nature_based_solutions_LT__policy_switch___fraction_of_land_with_riparian_buffers		01/01/2015	01/12/2049
2.1	3	Latvia	Nature based solutions	Fraction of land with nutrient treatment in LV: bioreactor and wetland	Extension of use of biorreactor and wetland system as a nutrient treatment alternative. The value represents the fraction of land (in Latvia) with nutrient treatment using a bioreactor and wetland system.	Nature_based_solutions_LV__policy_switch___fraction_of_land_with_bioreactor_and_wetland		01/01/2015	01/12/2049
2.2	4	Lithuania	Nature based solutions	Fraction of land with nutrient treatment in LT: bioreactor and wetland	Extension of use of biorreactor and wetland system as a nutrient treatment alternative. The value represents the fraction of land (in Lithuania) with	Nature_based_solutions_LT__policy_switch___fraction_of_land_with_bioreactor_and_wetland		01/01/2015	01/12/2049

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					nutrient treatment using a bioreactor and wetland system.				
3.1	5	Latvia	Nature based solutions	Fraction of land with nutrient treatment: biological farming	Extension of use of biological farming as a nutrient treatment alternative. The value represents the fraction of land (in Latvia) with nutrient treatment using biological farming.	Nature_based_solutions_LV__policy_switch___fraction_of_land_with_biological_farming		01/01/2015	01/12/2049
3.2	6	Lithuania	Nature based solutions	Fraction of land with nutrient treatment: biological farming	Extension of use of biological farming as a nutrient treatment alternative. The value represents the fraction of land (in Lithuania) with nutrient treatment using biological farming.	Nature_based_solutions_LT__policy_switch___fraction_of_land_with_biological_farming		01/01/2015	01/12/2049
4.1	7	Latvia	Land	Long-term policy: fraction of arable land with nutrients treatment in LV	This policy accounts for the fraction of the total arable land that will have nutrient treatment by 2050 in Latvia.	Land_LT__policy_switch___long_term_arable_land_fraction_NBS_objective		01/01/2015	01/12/2049
4.2	8	Lithuania	Land	Long-term policy: fraction of arable land with nutrients treatment in LT	This policy accounts for the fraction of the total arable land that will have nutrient treatment by 2050 in Lithuania.	Land_LV__policy_switch___long_term_arable_land_fraction_NBS_objective		01/01/2015	01/12/2049
5	9	Basin	Land	Long-term policy: fraction of grasslands used to install	This policy accounts for the fraction of grassland area that will be used to install renewable energy alternatives	Land__policy_switch___fraction_of_grasslands_to_renewables		01/01/2015	01/12/2049

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				renewables energies	(eolic and solar photovoltaic) by 2050.				
6.1	10	Basin	Land	On/Off policy: Allow conversion of arable land to grasslands	This policy allows to convert 10% of the arable land to grasslands during the first 12 years of the simulation.	Land__policy_switch___allow_conversion_arable_to_grassland		01/01/2015	01/12/2049
6.2	11	Latvia	Land	On/Off policy: Allow conversion of arable land to grasslands in LV	This policy allows to convert 10% of the arable land to grasslands during the first 12 years of the simulation.	Land_LV__policy_switch___allow_conversion_arable_to_grassland		01/01/2015	01/12/2049

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Annex III: CS3 policies (Jiu River Basin, Lower Danube)

N of policy	ID	Scale	Sector	Short name	Long description	SDM variable	Can not be applied with	Starting year	Ending year
1	1	National	Water	Sustainable management of the water resources (quantity)	Increase connectivity of population to public networks	Water_quantity__P1_Switch		01/01/2024	01/12/2030
2	2	National	Climate	Decarbonization and promoting renewable energy	Phasing out of all lignite coal and lignite-powered thermal power plants, with an objective for decarbonization and promoting renewable energy.	Climate__Switch_P2		01/01/2015	01/12/2049
3	3	National	Ecosystem	Protection of biodiversity	National campaign for aforestation and re-forestation including urban forests	Ecosystem__Switch_P3_Forest		01/01/2024	01/12/2026
4.1.1	4	Basin	Land	Extension of irrigated area	Strengthening the market orientation and increasing the competitiveness of agricultural farms	Land__P4_1_Switch_tot_maize_irr	5,6,7	01/01/2021	01/12/2030
4.1.2	5	Basin	Land	Extension of irrigated area	Strengthening the market orientation and increasing the competitiveness of agricultural farms	Land__P4_2_Switch_tot_maize_irr	4,6,7	01/01/2021	01/12/2030

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4.1.3	6	Basin	Land	Extension of irrigated area	Strengthening the market orientation and increasing the competitiveness of agricultural farms	Land__P4_3_Switch _tot_maize_irr	4,5,7	01/01/2021	01/12/2030
4.1.4	7	Basin	Land	Extension of irrigated area	Strengthening the market orientation and increasing the competitiveness of agricultural farms	Land__P4_4_Switch _tot_maize_irr	4,5,6	01/01/2021	01/12/2030
4.2.1	8	Basin	Land	Extension of irrigated area	Strengthening the market orientation and increasing the competitiveness of agricultural farms	Land__P4_1_Switch _tot_rapeseed_IRR	9,10,11	01/01/2021	01/12/2030
4.2.2	9	Basin	Land	Extension of irrigated area	Strengthening the market orientation and increasing the competitiveness of agricultural farms	Land__P4_2_Switch _tot_rapeseed_IRR	8,10,11	01/01/2021	01/12/2030
4.2.3	10	Basin	Land	Extension of irrigated area	Strengthening the market orientation and increasing the competitiveness of agricultural farms	Land__P4_3_Switch _tot_rapeseed_IRR	8,9,11	01/01/2021	01/12/2030
4.2.4	11	Basin	Land	Extension of irrigated area	Strengthening the market orientation and increasing the competitiveness of agricultural farms	Land__P4_4_Switch _tot_rapeseed_IRR	8,9,10	01/01/2021	01/12/2030
4.3.1	12	Basin	Land	Extension of irrigated area	Strengthening the market orientation and increasing the competitiveness of agricultural farms	Land__P4_1_Switch _tot_SUNFLOWER _irr	13,14,15	01/01/2021	01/12/2030
4.3.2	13	Basin	Land	Extension of irrigated area	Strengthening the market orientation and increasing the competitiveness of agricultural farms	Land__P4_2_Switch _tot_SUNFLOWER _irr	12,14,15	01/01/2021	01/12/2030
4.3.3	14	Basin	Land	Extension of irrigated area	Strengthening the market orientation and increasing the competitiveness of agricultural farms	Land__P4_3_Switch _tot_SUNFLOWER _irr	12,13,15	01/01/2021	01/12/2030

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4.3.4	15	Basin	Land	Extension of irrigated area	Strengthening the market orientation and increasing the competitiveness of agricultural farms	Land__P4_4_Switch_tot_SUNFLOWER_irr	12,13,14	01/01/2021	01/12/2030
5	16	National	Climate	GHG emission reduction from LULUCF	mainly through appropriate forest fires management	Climate__Switch_P5		01/01/2015	01/12/2049
6	17		Ecosystem	Protected habitats	Polder rehabilitation and construction, removing obstacles in the water courses and restoration of riparian habitats	Ecosystem__Switch_P6		01/01/2024	01/12/2027
7	18		Water	Increase RES% in gross final energy production (PNIESC)	Construction of new small hydro power plants taking into account environmental and social impacts 65 MW (AHE Bumbesti Livezeni) starting from 01.01.2024	Water_quantity__Switch_P7		01/01/2024	01/12/2049

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Annex IV: CS4 policies (Adige River Basin)

N of policy	ID	Scale	Sector	Short name	Long description	SDM variable	Can not be applied with	Starting year	Ending year
1.1	1	all basin	Water	Increase drip irrigation	Increase from 79% to 90% and 100% of orchards to drip irrigation by 2030	% orchards drip (water)		dic-30	dic-49
1.2	2	all basin	Water	Increase drip irrigation	Increase from 64% to 90% and 100% of vineyards to drip irrigation by 2030	% vineyards drip (water)		dic-30	dic-49
2.1	3	all basin	Land Use	Increase irrigated area	Increase from 59% of irrigated area of maize to 70% by 2030	irrigated maize area (land use)		dic-30	dic-49
2.2	4	all basin	Land Use	Increase irrigated area	Increase from 55% to 70% of the irrigated area of vineyards over the total area of vineyards by 2030	irrigated vineyards (land use)		dic-30	dic-49
2.3	5	all basin	Land Use	Increase irrigated area	Increase from 89% of irrigated area of orchards to 100% by 2030	irrigated orchards area (land use)		dic-30	dic-49
3.1	6	all basin	Land Use	Conversion to vineyards	Decrease of orchards area from 9% to 4,5% converting to vineyards (which will change from 8% to 15%) by 2030	Total orchard area (land use)		dic-30	dic-49
3.2	7	all basin	Land Use	Conversion to vineyards	Decrease of arable land (seminativi) area from 19% to 10% to vineyards (which will change from 8% to 17%) by 2030	Total maize area (land use)		dic-30	dic-49
4	8	all basin	Water	Reduce leakages	Reduce domestic water use leakage severity from 40% to 30% by 2040	Leakages severity (food)		dic-40	dic-49
5	9	all basin	Water	Reduce water consumption for residents	Reduce domestic water consumption of residents from 7,5m3/capita month to 4,5m3/capita month by 2040	Domestic water demand per cap (water)		dic-40	dic-49
6	10	all basin	Water	Reduce water consumption for tourists	Reduce water consumption of tourists from 22,5m3/capita month to 13,5m3/capita month by 2040	Touristic water demand per cap (water)		dic-40	dic-49

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7	11	all basin	Population	Limit tourist number of stays	Setting a limit to number of tourist stays to 4,1 milion of stays per year	Tourists change inflow (population)		dic-40	dic-49
8	12	all basin	Energy	Reduce energy consumption	Reduce domestic energy consumption of residents from 125kwh/capita month to 100kwh/capita and of tourists from 300 kwh/capita month to 250kwh/capita month by 2040	Domestic energy consumption (energy)		dic-40	dic-49

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Annex V: CS5 policies (Inkomati-Usuthu)

N of policy	ID	Scale	Sector	Short name	Long description	SDM variable	Can not be applied with	Starting year	Ending year
1	1		Land	Set up local food value chains	Investments to set up inclusive local food value-chains	Land_Use__P01		01/01/2015	01/01/2023
2	2		Land	Expand protected areas	Budget allocations and grants (public sector funding mechanisms) for protected area institutions to expand on protected areas	Land_Use__P02		01/01/2028	01/01/2038
3	3		Water	Biodiversity management and conservation	Develop and strengthen economic incentives to encourage appropriate investment by the private sector in biodiversity management and conservation, such as tax incentives, conservation agriculture incentives to farmers and others	Water__P03		01/01/2020	01/01/2030
4	4		Ecosystem	Protect biodiversity priority areas	Identification and registering & change of status of priority areas for ecological infrastructure and national biodiversity priority areas (including freshwater ecosystem priority areas)	Ecosystems__P04		01/01/2025	01/01/2035
5	5		Water	Improve water distribution systems	Investment in reparation of water distribution and treatment infrastructure and in maintenance and	Water__P05		01/01/2015	01/01/2030

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					monitoring of these systems to prevent leakage.				
6	6		Water	Improve water use efficiency	Monitoring of water usage to ensure effective water-supply planning, development and operation (Impose higher tariffs for excessive water usage and fines for excessive Nitrogen Runoff rates)	Water__P06		01/01/2025	01/01/2030
7	7		Climate	Stricter carbon emissions targets and taxes	Sectoral Emission Targets or SETs, which are quantitative greenhouse gas emission targets allocated to an emitting sector or sub-sector, over a defined time period (Carbon Tax, Fines for exceeding air emissions standards)	Climate__P07		01/01/2023	01/01/2033
8	8		Land	Expand protected areas	Budget allocations and grants (public sector funding mechanisms) for protected area institutions to expand on protected areas (similar to Policy 2)	Land_Use__P08		01/01/2023	01/01/2038
9and10	9		Land	Enhance food productivity	Subsidise or lower tariffs of the most expensive input material for production systems that contribute most to food security (Fertilizer/seed, lower electricity costs, bridging the knowledge gap)	Land_Use__P9and 10		01/01/2015	01/01/2023
11	10		Water	Efficient irrigation	Subsidies/incentives for adoption of more efficient irrigation techniques	Water__P11		01/01/2020	01/01/2030

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12	11		Energy	Renewable energy development	REIPPP (power purchase programme) that encourages renewable energy development	Energy__P12		01/01/2023	01/01/2030

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Annex VI: CS1 goals (Nestos River Basin)

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Annex VII: CS2 goals (Lielupe River Basin)

Goal ID	Goal name	Goal description	Indicator	Goal Target	Year	SDM variable	Operator	target	relative month
1	Reduce the long-term nitrogen concentration in the Lielupe River Basin (upstream - Lithuania)	Reduce the nitrogen concentration in the Lielupe River by 15% in 2050	Percentage of nitrogen concentration reduction compared with the baseline (2015)	15%	01/12/2049	Nature_based_solutions_LT__relative_nitrogen_reduction_rate	<=	[-0.15 for i in range(419,420)]	419
2	Reduce the long-term nitrogen concentration in the Lielupe River Basin (downstream - Latvia)	Reduce the nitrogen concentration in the Lielupe River by 20% in 2050	Percentage of nitrogen concentration reduction compared with the baseline (2015)	20%	01/12/2049	Nature_based_solutions_LV__relative_nitrogen_reduction_rate	<=	[-0.2 for i in range(419,420)]	419
3	Increase the renewable energy generation in the Lielupe River Basin up	Increase the renewable energy generation in the Lielupe River Basin to reach a potential of 700 GW/h by 2050	Renewable energy generation in the Lielupe River Basin in 2050		01/12/2049	Renewable_energy__Total_renewable_energy_generation	>=	[700000 for i in range(419,420)]	419
4	Reduce greenhouse gas emissions in the	80% of the CO2eq emmisions from arable land in the	Percentage of CO2eq emissions "compensated" from	80%	01/12/2049	Climate__Fraction_of_CO2eq_renewable_energy_s	>=	[80 for i in range(4	419

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	Lielupe River Basin	Lielupe are "compensated" by installing renewable energies in the Lielupe River Basin	installing renewable energies compared to the arable land emissions in the Lielupe River Basin			avings_compensated_from_GHG_arable_land_emmisions		19,420)]	
5	Increase the bird biodiversity	Increase bird biodiversity richness by 20% in 2027.	Increase bird biodiversity richness in the Lielupe River Basin compared with the baseline (2015)	20%	01/12/2049	Ecosystems__relative_change_in_bird_species_due_to_land_changes	>=	[20 for i in range(144,420)]	419

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Annex VIII: CS3 goals (Jiu River Basin, Lower Danube)

Goal ID	Goal name	Goal description	Indicator	Goal Target	Year	SDM variable	Operator	target	relative month
1	90% of population connected to water supply network by 2030	Increased connectivity of population to public networks	Water volumes taken by economic activities and intake sources (surface water and groundwater)	90%	01/12/2030	Water_quantity____PERCENT___of_people_connected_to_the_W_network_Derived_from_local_data_	>=	[0.9 for _ in range(191,420)]	191
2	87% GHG emission reduction in 2030.	Phasing out of all lignite coal and lignite-powered thermal power plants, with an objective for decarbonization and promoting renewable energy.	CO2 emissions intensity GHG emissions, by economic activities	87%	01/12/2030	Climate__emissions_tons_	<=	[0.13 * get_data_value (var=self.sdm_variable, month=0, data=self.baseline) for _ in range(191,420)]	191
3	97% GHG emission reduction in 2050.	Phasing out of all lignite coal and lignite-powered thermal power plants, with an objective for	CO2 emissions intensity GHG emissions, by economic activities	97%	01/12/2049	Climate__emissions_tons_	<=	[0.03 * get_data_value (var=self.sdm_variable, month=0, 146data=self.b	419

NEXOGENESIS
STREAMLINING WATER RELATED POLICIES

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		decarbonization and promoting renewable energy.						aseline) for _ in range(419,420)]	
4	56700 ha in 2026 (at national level) - new afforestated or re-forestated surfaces. The % of forest increase at the basin level is 5% (2835 ha) of the national expected afforestation	National campaign for aforestation and re-forestation including urban forests	Forest area	5%	01/12/2026	Ecosystem__Tot_forests_	>=	[(0.05 *56700) + get_data_value (var=self.sdm_variable, month=107, data=self.baseline) for _ in range(143,420)]	143
5	30% increase in irrigated surface for Maize	30% increase in irrigated surface for Maize	Maize irrigation land	30%	01/04/2031	Land__Maize_IRR_land__ha__policy_yes_no_	>=	[get_data_value(var="Land__P4_1_30__PERCENT___increase_of_IRR_MAIZE_from_2020_to_2030", month=i, data=self.baseline) for i in range(195,420)]	195
6	30% increase in irrigated surface for Rapeseed	30% increase in irrigated surface for Rapeseed	Rapeseed irrigation land	30%	01/04/2031	Land__RAPESEED_IRR_land	>=	[get_data_value(var="Land__P4_1_30__PE	195

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						__ha__policy_yes_no_		RCENT___increase_of_IRR_RAPESEED_from_2020_to_2030", month=i, data=self.baseline) for i in range(195,420)]	
7	30% increase in irrigated surface for Sunflower	30% increase in irrigated surface for Sunflower	Sunflower irrigation land	30%	01/04/2031	Land__SUNFLOWER_IRR_land__ha__policy_yes_no_	>=	[get_data_value(var="Land__P4_1_30__PERCENT___increase_of_IRR_SUNFLOWER_from_2020_to_2030", month=i, data=self.baseline) for i in range(195,420)]	195
8	17% GHG removals increase by 2030	mainly through appropriate forest fires management	Climate forest seq	17%	01/12/2030	Climate__forest_seq_	>=	[1.17 * get_data_value(var=self.sdm_variable,month=0,data=self.ba	191

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								seline) for _ in range(191,420)]	
9	31% GHG removals increase by 2050	mainly through appropriate forest fires management	Climate forest seq	31%	01/12/2049	Climate__forest _seq_	>=	[1.31 * get_data_value (var=self.sdm_ variable,month =0, data=self.basel ine) for _ in range(419,420)]	419
10	Wetland area increased 10% more at the end of 2027 compared to 2023.	Polder rehabilitation and construction, removing obstacles in the water courses and restoration of riparian habitats	Total wetland	10%	01/12/2027	Ecosystem__Tot _wetland_3_	>=	[1.1 * get_data_value (var=self.sdm_ variable,month =191, data=self.basel ine) for _ in range(155,420)]	155
11	Allocate 15% of surface water for hydropower production to increase RE in the energy mix	Increase RES% in gross final energy production (PNIESC) Construction of new small hydro power plants taking	Allocation of surface water for hydropower production	15%	01/01/2024	Water_quantity_ _Tot_Hydropow er_Outflow_M m3_	>=	[get_data_valu e(var="Water_ quantity__P7_ New_water_all ocation_",mont h=i, data=self.basel	108

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		into account environmental and social impacts 65 MW (AHE Bumbesti Livezeni) starting from 01.01.2024						ine) for i in range(108,420)]	

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Annex IX: CS4 goals (Adige River Basin)

Goal ID	Goal name	Goal description	Indicator	Goal Target	Year	SDM variable	Operator	target	relative month
1	Increase water use efficiency/Save water in agriculture	To save 25% of water used (average annual usage compared to the baseline) for agricultural purposes by 2040	Agriculture water demand (water)		dic-30	Agriculture water demand (water)	<=	25	192
2	Reduce population water consumption	Reduce population water consumption of 15% by 2050	Domestic water withdrawal (water)		dic-40	Domestic water withdrawal (water)	<=	15	312
3	Reduce population energy consumption	Reduce population energy consumption of 20% by 2050	Domestic energy consumption (energy)		dic-40	Domestic energy consumption (energy)	<=	20	312

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Annex X: CS5 goals (Inkomati-Usuthu)

Goal ID	Goal name	Goal description	Indicator	Goal Target	Year	SDM variable	Operator	target	relative month
1	IRP (2023) Renewable energy goal	Achieve Renewable Energy Targets as set out by the 2023 Draft Integrated Resource Plan for national electricity supply	Percentage renewable energy supply [Energy__Ratio_RN]	Greater than 20.3%	01/01/2030	Energy__Ratio_RN	>=	[0.203 for _ in range(180,420)]	180
2	NDC 2030 Emissions Targets (Lower Limit 350 Mt CO2-eq)	Reduce emissions to achieve the lower limit of the 2030 Nationally Determined Contributions (Sept 2021) GHG Emissions Target of 350 Mt CO2-eq	GHG emissions [Climate__Co2e_emissions]	Reduce by 26.5% of 2019 GHG emissions	01/01/2030	Climate__Co2e_emissions	<=	[0.735 * get_data_value(var=self.sdm_variable, month=48, data=self.baseline) for _ in range(180,420)]	180
3	NDC 2030 Emissions Targets (Lower Limit 350 Mt CO2-eq)	Reduce emissions to achieve the lower limit of the 2030 Nationally Determined Contributions (Sept	GHG emissions [Climate__Co2e_emissions]	Reduce by 11.76% of 2019 GHG	01/01/2030	Climate__Co2e_emissions	<=	[0.8824 * get_data_value(var=self.sdm_variable, month=48, data=self.basel	180

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		2021) GHG Emissions Target of 420 Mt CO2-eq		emissions				ine) for _ in range(180,420)]	
4	Reduce urban water demand as per NDP	Reduce urban water demand as per the National Development Plan by 15% by 2030	Domestic water withdrawal [Water__Domestic_water_withdrawal]	Reduce by 15%	01/01/2030	Water__Dom_water_with_P05	<=	[0.85 * get_data_value (var=self.sdm_variable, month=0, data=self.baseline) for _ in range(180,420)]	180
5	Reduce industrial water demand as per the National Water & Sanitation Masterplan	Reduce industrial water demand as per the National Water & Sanitation Masterplan by 10% by 2026	Industrial water withdrawal [Water__Industrial_water_withdrawal]	Reduce by 10%	01/01/2026	Water__Ind_water_with_P05	<=	[0.90 * get_data_value (var=self.sdm_variable, month=12, data=self.baseline) for _ in range(132,420)]	132
6	Reduce agricultural (crops) water demand per unit of production as per the National Water & Sanitation Masterplan	Reduce agricultural (crops) water demand per unit of production by 10% as per the National Water & Sanitation	Crop per drop [WEFE_Index__Crop_per_drop]	Increase by 11%	01/01/2030	WEFE_Index__Crop_per_drop	>=	[1.11 * get_data_value (var=self.sdm_variable, month=12, data=self.baseline) for _ in	180

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		Masterplan by 2030						range(180,420)]	
7	Reduce agricultural (livestock) water demand per unit of production as per the National Water & Sanitation Masterplan	Reduce agricultural (livestock) water demand per unit of production by 10% as per the National Water & Sanitation Masterplan by 2030	Livestock water demand per unit produced [Goal7__Indicator7]	Reduce by 10%	01/01/2030	Goal7__Indicator7	<=	[0.90 * get_data_value (var=self.sdm_variable, month=12, data=self.baseline) for _ in range(180,420)]	180
8	Maintain minimum maintenance flows and basic human needs as per the National Water Act	Maintain minimum maintenance flows and basic human needs of 24.5% of total surface water runoff as per the Reserve determination for the catchment as published under the National Water Act	Water Balance [Water__Water_balance]	Great than 24.5% of Surface Water Runoff [Surface_water_runoff__SWR_Inkomati]	Maintain	Water__Water_balance	>=	[0.245 * get_data_value (var="Surface_water_runoff__SWR_Inkomati",month=i, data=self.baseline) for i in range(0,420)]	0
9	Meet transboundary requirements on a yearly basis	Meet transboundary requirements as defined by the	Water Balance [Water__Water_balance]	Greater than 0	Maintain	Water__Water_balance	>	[0 for i in range(0,420)]	0

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		Progressive Realization of the IncoMaputo Agreement developed by the Tripartite Technical Committee between Mozambique, South Africa and Swaziland							
10	Maintain nitrogen concentrations below 2.5 mg/L	Maintain nitrogen concentrations below acceptable levels of 2.5 mg/L as defined by South African Water Quality Guidlines (Volume 7 Aquatic Ecosystems)	N Concentration [WEFE_Index__N_concn]	Less than 2.5 mg/L	Maintain	WEFE_Index__N_concn	<=	[2.5 for i in range(0,420)]	0
11	Increase protected areas to achieve goals set out in the NPAES 20 year targets	Increase protected areas to achieve goals set out in the 2018 National Protected Area Expansion Strategy's 20 year target which is	Protected Areas [Land_Use__Total_area_in_SAPAD]	Increase by 28%	01/01/2038	Land_Use__Total_area_in_SAPAD	>=	[1.28 * get_data_value (var=self.sdm_variable,month=0, data=self.baseline) for i in	276

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		equivalent to a 28% increase						range(276,420)]	
12	Ensure no species status declines as per NBSAP	Maintain mean species richness above 2015 levels to ensure no species status declines as per the National Biodiversity Strategy and Action Plan	Average Annual Mean Species Richness (Amphibians) [Mean_species_richness__Amphi_species_richness] Average Annual Mean Species Richness (Birds) [Mean_species_richness__Birds_species_richness] Average Annual Mean Species Richness (mammals) [Mean_species_richness__Mammals_species_richness]	Greater than the 2015 average	Maintain	Mean_species_richness__Amphi_species_richness	>=	[get_data_value(var=self.sdm_variable,month=0, data=self.baseline) for i in range(0,420)]	0

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13	National Food And Nutrition Security Plan For South Africa, 2023 Targets for subsitence production	Increase subsistence farming production to achieve 2023 Targets as per National Food And Nutrition Security Plan For South Africa	Rainfed Subsistence area [Land_Use__Rainfed_subsistence_area]	Increase by 700% of 2018 value	01/01/2023	Land_Use__Rainfed_subsistence_area	>=	[7 * get_data_value(var=self.sdm_variable,month=0, data=self.baseline) for i in range(96,420)]	96
14	Ensure food security within the catchment is maintained or improved	Ensure that local food production growth is greater than expected pouplation growth within the catchment	Local Food Prodution Growth [Goal14__Indicator14]	Greater than Local Population Growth [Goal14__Target14]	Maintain	Goal14__Indicator14	>=	[get_data_value(var="Goal14__Target14",month=i, data=self.baseline) for i in range(0,420)]	0

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