JUST2CE

A Just Transition to Circular Economy

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A DECISION SUPPORT TOOL FOR A JUST TRANSITION TO A CIRCULAR ECONOMY

D4.2: Software: DSS Beta Version

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2. UNIVERSIDAD DE VIGO
3. THE UNIVERSITY OF SHEFFIELD
4. UNIVERSITA DEGLI STUDI DI NAPOLI PARTHENOPE
5. CENTRO DE ESTUDOS SOCIAIS
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13. AFRICAN CIRCULAR ECONOMY NETWORK
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A Just Transition to Circular Economy

PROJECT No. 101003491

JUST2CE will assess the current state of transition towards the Circular Economy in relevant economic sectors and analyse possible transition scenarios, as well as their outcomes and impacts. It will identify the key factors that can stimulate or hinder this transition. Natural resources are extracted and transformed into products, which are eventually discarded. As many natural resources are finite, it is important to keep materials in circulation for as long as possible. This makes the transition to Circular Economy more vital than ever but is a responsible, inclusive, and socially just transition to a Circular Economy possible or even desirable? What technical, political, and social factors can enable or hamper such transformation? The EU-funded JUST2CE project will answer these questions. It will explore the economic, societal, gender and policy implications of the Circular Economy paradigm. The project's findings will shed light on how to ensure democratic and participatory mechanisms when designing and managing such technology.

History Chart

Version	Date	Implemented by
V0.1	04/10/2023	Elena Conte, Giuseppe Mastandrea, Luigi D'Oriano, Giuseppe Rana, Marco Antonio Insabato, Cosimo Liuzzi
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V1.0	24/11/2023	Elena Conte, Giuseppe Mastandrea, Luigi D'Oriano

Disclaimer

Executive Summary

The purpose of this document is to describe the developed JUST2CE Decision Support Tool (DST), as one of the results of Work Package (WP) 4, strictly related to Task 4.4: implementation and deployment.

The DST is intended as a learning tool aimed to support users in investigating typical supply chains at the global level by automatically performing analyses on relevant large datasets. The aim of the tool is to support users to explore supply chains, and better understand their complexity on the global scale via the visualization and association of the results with each country in a world map. The users can evaluate the results of the operations performed automatically, expressed in numerical percentages of the impact of contributing sectors within the selected supply chain of interest. The tool also integrates other findings from JUST2CE, including WP2's case studies, so that users can evaluate the relations of the supply chains with such aspects of the project.

The features and the functionalities of the DST have been discussed and selected through a series of dedicated meetings between the interested consortium partners, identifying the main needs and requirements of the project which should be covered by the tool. In this way, the DST is tailored and customized based on the case studies and theoretical framework of the project, but at the same time it has the potential to be scaled-up and expanded in order to cover wider areas and include other case studies, stories, and findings in the future.

The DST will be tested in subsequent tasks of the project to strengthen the impact of JUST2CE by involving external stakeholders such as policy makers with the aim to collect feedback to assess and refine the tool. To this end, the comments and experiences gained during the testing phase of the tool will be analysed and will serve as improvement materials for the DST to further meet the requests and needs of the final users.

JUST2CE
A Just Transition to Circular Economy

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List of abbreviations

DST	*Decision Support Tool*
DTO	*Data Transfer Object*
GTAP	*Global Trade Analysis Project*
IO	*Input-Output*
MF	*Macro-Functionality*
MRIO	*Multi-region input-output*
OECD-ICIO	*Organization for Economic Co-operation and Development Inter-Country Input-Output*
WP	*Work Package*
WIOD	*World Input-Output Database*

1. Introduction

In recent years, market opportunities have overcome regional barriers becoming more and more globalized, and in certain cases also circular. This has led to a new range of perspectives, and business and economic opportunities outside each region and across different sectors and countries. However, it is difficult to track and identify socioeconomic aspects, issues of justice, and just practices within such complex and nested supply chains. Just practices may be considered as the concrete implementation of the so-called Just Transition, which can be interpreted as [1]:

- A principle, representing a fair, inclusive and equitable transition towards a more environmental and social economy having people as the core, or
- A process, which requires a compromise with geographical, political, environmental, cultural and socio-economic considerations.

According to the International Labour Organization [2], just practices span a broad range of sectors and contexts, relying on inclusiveness and social justice. Other dimensions refer to job creation, social inclusion through equal access to energy and services, gender equality, environmental justice, global health, natural ecosystem preservation, and eradication of poverty.

The just practices not only include social aspects, but also economic and social perspectives that are often not clearly visible at a first glance. These aspects are gaining the interest of the scientific community, researchers and scholars, in order to conduct social studies that might trigger also political decision making.

In this complex and evolving context, the JUST2CE projects aims at analysing aspects as inclusivity, social factors and geopolitics involved in the transition to a Circular Economy (CE) on the global scale. Core to the theoretical framework are themes relating to gender justice, labour justice, and global environmental justice, as well as principles of responsible research and innovation, and decoloniality. The success stories identified by the project will be used to improve existing CE practices and to demonstrate positive results already detected.

Analysing supply chains through consideration of these perspectives and practices is not straightforward. Different tools exist in the literature, as described in following chapters, to support researchers and scholars in this study. However, the development of ad-hoc innovative features was conceived in order to better reinforce and highlight the impact of the JUST2CE results, which are included in a dedicated Decision Support Tool (DST) as described in the present deliverable.

At first, within the initial project grant proposal, the DST was proposed to be “capable of assessing the current and potential degree of circularity of a given unit of analysis… assess[ing] the ability of production systems to reduce resource consumption while producing a positive socio-economic impact” [3]. Afterwards, following the project’s evolution, its scope and objectives have been changed to be better aligned to the target of the JUST2CE context, and the needs and work of other WPs, reaching its final goal as a learning tool. Therefore, the DST is intended as a learning platform, targeting a wide audience of users including researchers, practitioners, and policy makers, aimed to illustrate typical supply chains and linked surrounding aspects related to the project’s core themes.

In line with the final form and features of the DST, Section 2 starts with a description of the theory of Multi-Regional Input-Output (MRIO) analysis, and the Leontief model. This is important to understand the background context in which the DST was born, with a particular focus on the EXIOBASE dataset as the main source of data for the tool. Then, Section 3 presents a comprehensive state of the art analysis of similar tools existing in the literature, including benefits and disadvantages of each tool. Such consideration was useful to further refine the features and the characteristics of the

JUST2CE tool. Finally, Section 4 continues with an explanation of the core features of the DST, including a description of how the EXIOBASE matrices are utilised, relevant numerical values, and the operations performed on the calculated data, including macro functionalities both at backend and frontend level.

2. Supply Chains and economic models

A supply chain is a group of entities involved in the production, delivery and consumption of goods and services [4], usually starting from the production of raw materials, through the carriers and internet networks delivering products and software services until the final consumers. A supply chain also considers domains such as marketing, operations, distribution, finance, and customer service related to the products and services produced and sold. The process of organization, administration, and optimization of the supply chains on different levels and size scales is called supply chain management [5]. Many actors including producers, warehouses, vendors, carriers, and distribution centres are involved in a supply chain, and effective supply chain management can impact overall costs and profit by lowering economic losses. It is thus essential to model a supply chain in order to be able to optimize the overall process whilst ensuring economic sustainability and traceability of suppliers and consumers.

However, since most modern supply chains are global, modelling can be complex, involving many entities and different levels, it should be also flexible enough to reflect the constantly changing market. To this aim, different models have been developed to meet the requirements of companies to reflect their different structures and their specific needs [4]:

- **Continuous Flow Model**: a traditional supply chain model for companies that produce the same amount of goods with little fluctuations. It requires an advance management and control on the restock of primary materials in order to prevent bottlenecks [6] ,
- **Fast Chain Model**: a model that focuses on the market trends that influence production. Thus, production speed and market analysis are crucial here,
- **Flexible Model**: a model that reflects the seasonal production of a set of goods (for instance holiday merchandise). Since the demand for these types of products changes over time, this model ensures that the companies are able to rapidly begin production during high demand spikes and efficiently reduce it as demand tapers off. In this model, the forecasts of restock, inventory and, labour over time is crucial.

Beyond conceptual models for companies to manage and understand their internal supply chains, there have been developed deeper and more complex simulation models to describe the supply chains on the regional and sectoral levels. As well as the interest of companies to maximise their own profit, researchers and policy makers have been interested in modelling and investigating supply chains on the global scale in this way. Such simulation approaches can identify critical points for the attention of political intervention, such as identifying aspect relating to injustice, the protection of human rights, and aspects relating to negative environmental impacts. This has led to the establishment of nested models which incorporate social impacts as well as economic factors, an example of such an approach may be found in the use of Multi-Regional Input-Output (MRIO) analysis, described in the following section.

2.1. Multi Regional Input Output analysis

In the 1930's, Wassily Leontief created the input-output (IO) model, which uses matrices to represent a single economy. The standard IO model assumes that the economy is composed of a number of sectors, each of which produces goods and services for each and every other sector, including itself. Therefore, the sectors are inter-dependent and the total input always equals the total output. Leontief developed two types of models, open models and closed models [7].

Closed IO models are simpler and are based on the assumption that each sector sells products and services to other sectors and for auto-consumption directly. Therefore, the models can be expressed by the simple formula

$$X = AX$$

where X is the final demand and A is the IO matrix, which expresses the relations between the productive and consuming sectors.

On the other hand, open IO models are more realistic as they consider the fact that a portion of the goods and services produced not only meet the demand of other sectors, but also serve third-party customers. Nonetheless, the background assumption is still that all that is being produced is also being consumed.

In this case, the model equation is more complex and is the following:

$$X = AX + Y$$

which considers, with respect to the formula used in the closed model, the addition of the external demand Y. It is possible to transform the previous equation in order to isolate the final demand X, eventually obtaining the final and fundamental formula

$$X = (I - A)^{-1} Y$$

where I is the identity matrix, and the matrix $(I - A)^{-1}$ is the Leontief matrix.

MRIO analysis is an extension of the single-country Leontief model which tracks financial flows between countries' major economic sectors. It allows investigation of how industries in a given region impact on the production of industries in other regions, allowing a method for expressing the globalized complexity of supply chains. MRIO can also be extended to estimate resource flows by integrating data from National Footprint and Biocapacity Accounts.

IO tables represent the economic activities (output) of the economy, whose columns are the production sectors and the categories of final demand. The rows of IO tables are the corresponding intermediate input of these activities and sectors as well as their primary inputs.

There are various sources of data for MRIO models available. The most known are the Global Trade Analysis Project (GTAP) [8], World Input-Output Database (WIOD) [9], Organization for Economic Co-operation and Development Inter-Country Input-Output (OECD-ICIO) [10], EORA MRIO [11] and EXIOBASE [12].

EXIOBASE was chosen for the purposes of the DST, due to reasons of free access to data and its coverage, as outlined in D4.1 [13]. Therefore, its theory is described in the following subsection as an example of a MRIO dataset. A preliminary and extensive effort by the modelling team was necessary to understand the theory behind the maths and economics of the MRIO analyses, based on the Leontief model. In collaboration with the consortium partners involved in the development activities of the DST, an extensive study and analysis of the EXIOBASE model has been performed. The findings of this study have been employed, together with a constant alignment amongst the partners, ad-hoc in-depth documents provided by USFD, with their expertise on the analysis of such data flows. It has thus been possible for the modelling team at E@W to perform the modelling of the theoretical operations on the EXIOBASE matrices in order to define the way forward for subsequent coding activities, as described in the next section.

2.2. MRIO Tables and EXIOBASE

EXIOBASE 3 is the outcome of the FP7 DESIRE project [14], which is based on the previous work conducted on EXIOBASE 2 in the CREEA FP7 project [15] and on EXIOBASE 1 in EXIOPOL FP6 project [16].

It provides MRIO tables for 163 sectors per each of 44 countries (28 in Europe, plus16 'major economies'), and 5 rest of the world regions, with annual datasets ranging from 1995 to 2022. The dataset selected to be used within the DST is 2022, to provide the users with the latest updated information available.

The IO paradigm is built upon tabulated information concerning the flows of products from each sector, the producer, to each of the other sectors, including itself, which are considered as consumers.

	Sectors	Intermediate Demand			Final Demand	Total Output
		Agriculture Sector	Manufacturing Sectors	Service Sector		
Domestic Production	Agriculture Sector	z_{11}	z_{12}	z_{13}	f_1	x_1
	Manufacturing Sector	z_{21}	z_{22}	z_{23}	f_2	x_2
	Service Sector	z_{31}	z_{32}	z_{33}	f_3	x_3
Imports		m_1	m_2	m_3	mf	m
Value Added	Profits	π_1	π_2	π_3		π
	Wages	w_1	w_2	w_3		w
Government	Indirect taxes	t_1	t_2	t_3		t
	Total Outlays	x_1	x_2	x_3	f	x

Figure 1 stylised representation of an IO table based on Miller and Blair analyses [17]

Figure 1 depicts a stylised IO table, colour coded with reference to its dimensions. The value of production (output) of each sector is represented in the *rows* of the IO table, and is disaggregated into its 'destinations', i.e., whether its output is demanded by other sectors **('Intermediated Demand')** as inputs to their own production process, or if it is demanded for final use (**'Final Demand'** components: Household or Government Consumption, Investment, or Exports). Each sector's expenditure is represented by the *columns*. A sector revenue is spent on intermediate inputs purchased from other sectors **('Domestic Production')**, paid to workers as wages or distributed as profits to capitalists **('Value-Added')** or paid as indirect taxes to the state **('Government').** In a single country, **'Imports'** demanded either as inputs in production or directly as final demand are represented in a single row.

The rows of such a table describe the distribution of a producer's output throughout the economy. The columns describe the composition of inputs required by a particular industry to produce its output. In a multiregional setting, the IO tables of multiple countries are combined into a single table, where the imports and exports vectors are disaggregated according to sectors and countries of origin and destination.

In a multiregional setting, the IO tables of multiple countries are combined into a single table, where the imports and exports vectors are disaggregated according to sectors and countries of origin and destination (as shown in Figure 2).

2 x 2 country with 3x3 industries MRIO		Country A			Country B			Country A	Country B	
		Intermediate Demand			Intermediate Demand			Final Demand		Total Output (at basic prices)
Country	Sectors	Agriculture	Manufacturing	Services	Agriculture	Manufacturing	Services			
Country A	Agriculture	Intermediate inputs demanded by sectors located in country A from sectors located country A			Intermediate inputs demanded by sectors located in country B from sectors located country A			Domestic final demand for goods produced in country A	Foreign final demand for goods produced in country A	Total output of Country A
	Manufacturing									
	Services									
Country B	Agriculture	Intermediate inputs demanded by sectors located in country A from sectors located country B			Intermediate inputs demanded by sectors located in country B from sectors located country B			Foreign final demand for goods produced in country B	Domestic final demand for goods produced in country B	Total output of Country B
	Manufacturing									
	Services									
Value Added	Profits	Value added in Country A			Value added in Country B					
	Wages									
Total Outlays (at basic prices)		Total outlays per sector in country A			Total outlays per sector in country B					

Figure 2 stylised representation of a MRIO table in basic prices

From a practical perspective, the IO analysis fundamental equation, as already described, is the following:

$$x = (I - A)^{-1} f_d$$

This equation describes the amount of total output (x) required to be able to satisfy a given final demand (f_d), this is achieved by pre-multiplying the final demand (f_d) vector by the Leontief inverse matrix $(L = (I - A)^{-1})$, also referred to as the total requirements matrix, where I is an identity matrix with 1 in the diagonal and 0 in the other elements, and A is the technical coefficient matrix. As such the Leontief inverse captures the impact of final demand throughout the entire supply chain.

Due to the size and complexity of the MRIO tables to be used for the scopes of the DST, the table as represented in abstract in Figure 1 is split across a number of separate files. Figure 3 indicates which sections of the MRIO table are stored in which files provided by EXIOBASE:

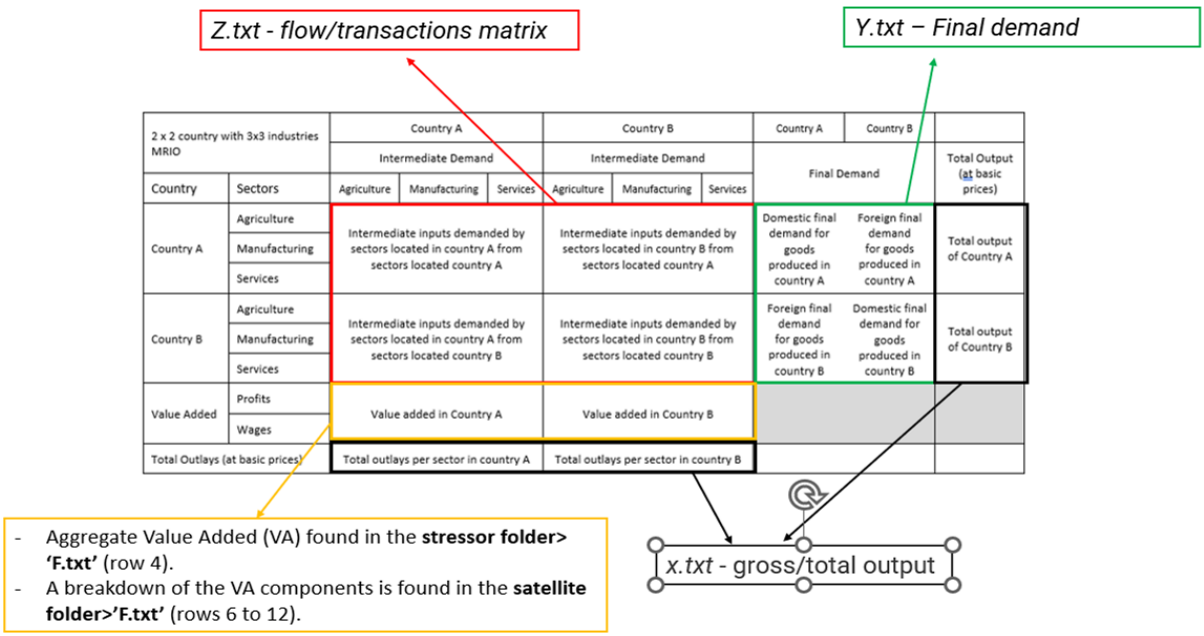

Figure 3 Association between EXIOBASE main files and the stylised representation of a MRIO table in basic prices

The files containing the economic core of the IO tables are comprised of the following:

- ***Z.txt* - flow/transactions matrix**
  - *Matrix containing total intermediate demand from sectors located domestically or in foreign country, represented by Z in the equations.*
- ***A.txt* - matrix/inter-industry coefficients, (direct requirements matrix)**
  - *Matrix compiling the technical coefficients, represented by A in the equations.*
- ***Y.txt* - final demand**
  - *Matrix compiling the final demand for each sector's output disaggregated into its components (Final Consumption of Households, Non-profit organizations, and government, Gross Fixed Capital Formation, Change in inventories). Represented by f_d in the equations.*
- ***x.txt* - gross/total output**
  - *Matrix compiling the total/gross output in each sector in each country*. Represented by x in the equations.
- ***unit.txt* - Units of the flow data**
  - *Matrix containing the unit of account of each variable included in the files above.*

The Leontief inverse matrix ($L = (I - A)^{-1}$), whose column sums expresses output multipliers (also referred to as backward linkages depending on the application), is not directly provided and needs to be calculated.

3. Overview of existing MRIO tools to investigate supply chains and justice

The first step performed in the implementation phase has been the analysis of similar solutions available in the literature to investigate supply chains and justice issues on the global scale. This preliminary study was important to know what is already available to researchers and stakeholders, and to identify critical aspects that were partially covered or dealt with in an insufficient fashion, and finally to deduce concepts and requirements for the features the JUST2CE DST tool should present. Therefore, the structure and visualization elements exploited in the DST tool are based on the highlights and results of the analysis of the characteristics of the following tools.

3.1. Eora Global MRIO

The Eora global supply chain database [11] provides MRIO tables with matching environmental and social impacts on 190 countries across almost 16000 sectors over a 30 years-long time period. The total number of related applications available on the site is 7, namely:

1. Supply Chain Explorer,
2. Sector/product-level footprints,
3. National carbon footprints,
4. Environmental footprints,
5. Heatmap visualization,
6. City footprints,
7. Global value chains.

In particular, the Supply Chain Explorer, which is the most interesting for the DST specifications, offers the possibility for the user to select a country and the sector to explore input-output flows documented in Eora. The left side represents the input to the selected sector, the right side is where the output is sold, and the arrows represent the direct suppliers (tier 1), their suppliers (tier 2), their suppliers' suppliers and so on. The basic free demo version only allows to explore the country Vietnam, while the entire tool covers all countries with multipliers.

Figure 4 Supply Chain Explorer Demo version [11]

Unfortunately, it is mandatory to purchase a quite expensive Eora license in order to investigate wider scenarios with other countries and sectors. Moreover, the visualization might not be straightforward and easily understandable for a new user, and the documentation offers a limited explanation and support on how to interpret the tool. Therefore, we could deduce the requirement for the JUST2CE DST to be open-source and freely accessible, presenting an easier, clearer and more attractive user interface and visualization dashboard.

3.2. Manifest!

Manifest! [18] is a toolkit to visualize, analyse and document supply chains on the global scale, mainly aimed for researchers, journalists, students, and scholars. It is aimed to provide a common data and file standard for supply chains, visualize supply chains on a simple and interactive map, and evaluate critical supply chain metrics. The system is flexible, lightweight, descriptive, free and opensource, and can handle a wide variety of file formats and data sources, both native or user uploaded. It is not based on commonly recognized Supply Chains Databases (i.e., Eora, EXIOBASE, World Input-Output Database (WIOD) etc), but it allows users to freely define their supply chains files and structures directly in the tool.

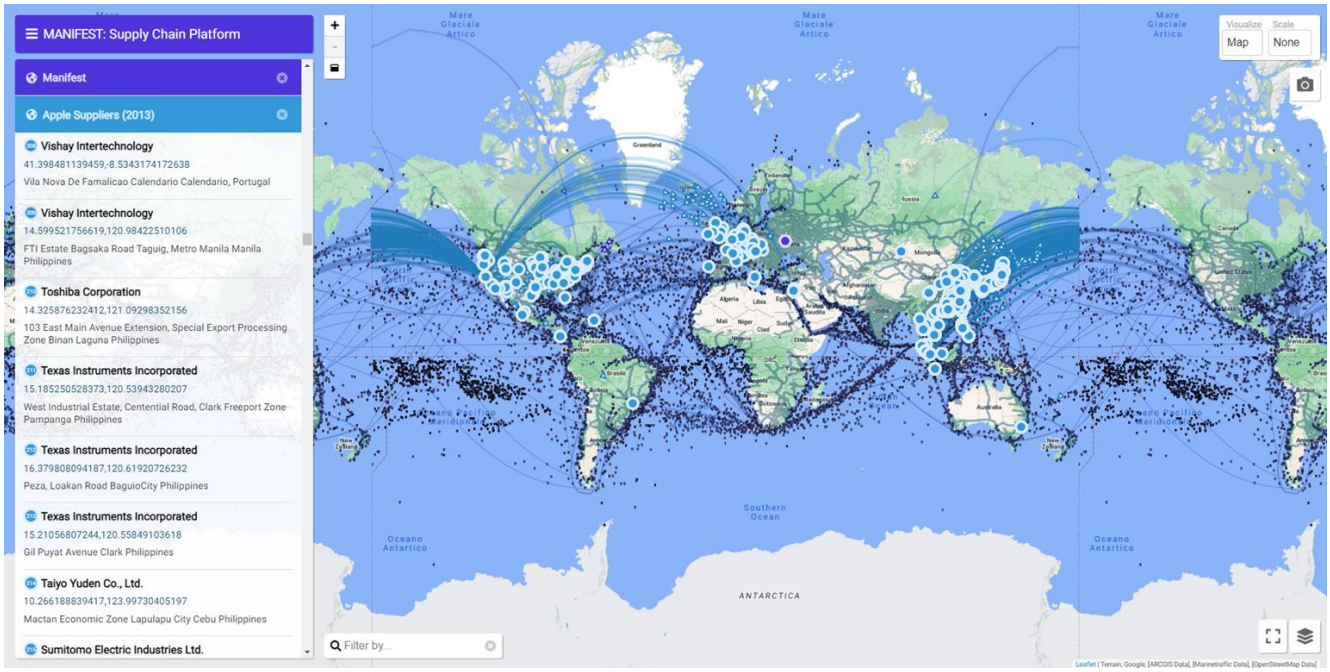

Figure 5 Manifest! Supply Chain Platform

Although the code is freely accessible, the file standard for the supply chain data is not defined yet, and there is not a control access or authorization control mechanism to check who is adding files to the database and the quality of the information inserted. Moreover, as can be seen in Figure 5, it presents some issues with the visualization and clarity of the displayed map. Furthermore, the information displayed on the list on the left seems static and not of great impact or meaning, and the users cannot easily select the country and sector of the supply chain they are willing to investigate.

It can be deduced that the JUST2CE DST should be simpler in terms of file formats handled and supply chains drown on the map, but the information displayed should be clearer, more focused on results from the MRIO tables, and meaningful for the users to perform domain analyses and statistical evaluations on the desired country/sector choices.

3.3. Environmental Footprints

Environmental Footprints [19] is a research group specialised in MRIO analysis and development at the Industrial Ecology Programme at NTNU. The group have developed 3 online data and visualization applications:

The *Data Explorer* is a web tool to query and export data from different MRIO and supply chain models and versions (Eora, EXIOBASE, WIOD, GTAP, OECD-ICIO), using options as years, parameters, regions, sectors and stressors.

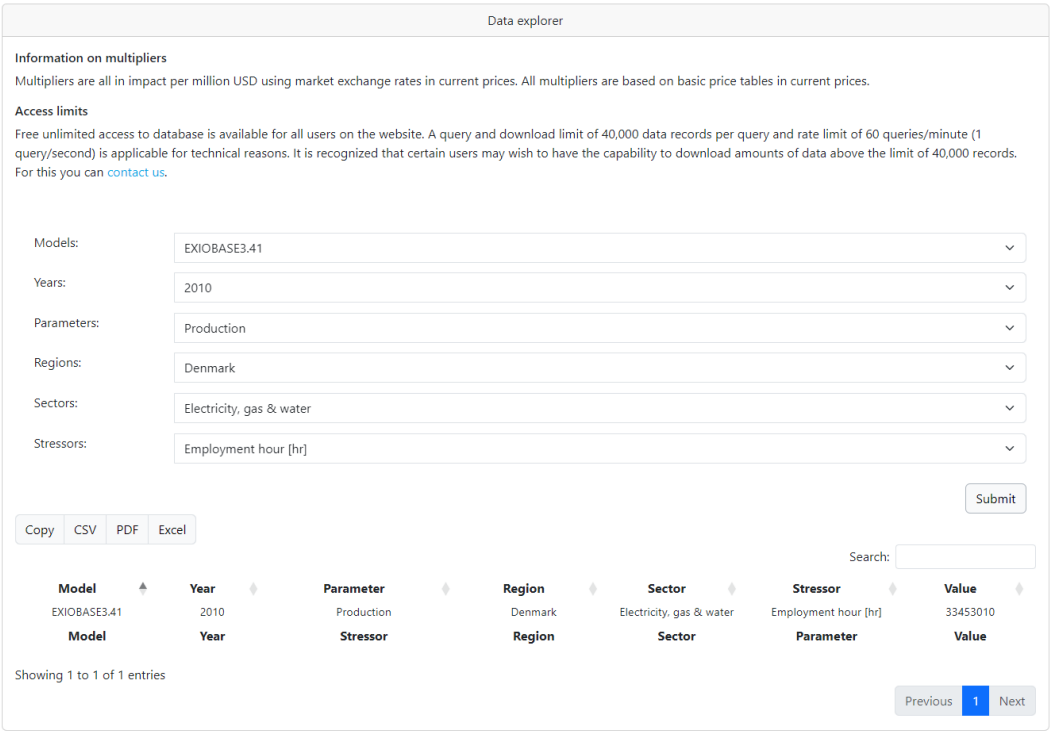

Figure 6 Environmental Footprints - Data explorer

Infographics is the main visualization dashboard to show consumption-based environmental impacts calculated for the user-selected selectors in terms of stressor, sector, model and country,

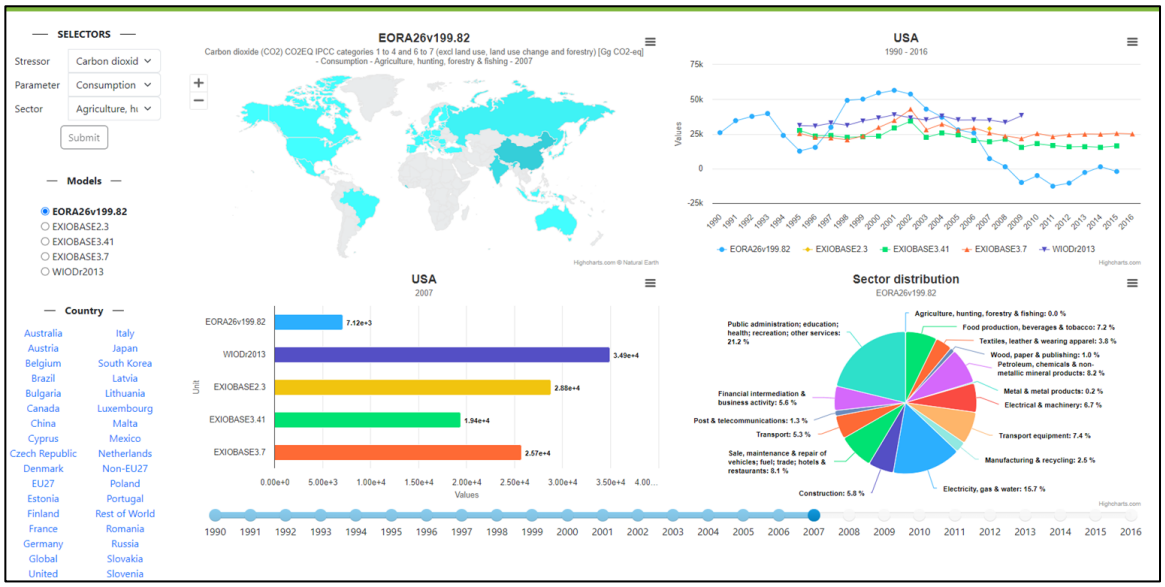

Figure 7 Environmental Footprints - Infographics

Despite the variety and richness of the information visualized, which includes a world map, timelines, histograms and pie charts customizable in terms of model used, country and year considered, the dashboard appears quite dense and confusing and not easily and immediately understandable.

EXIOBASE 3: based on selectors as stressor, parameter (i.e., production, consumption, net-trade etc.), and year, the tool visually represents the queries done on the EXIOBASE database on the selected country through a world map, a line chart plotting results over time, and a pie chart for the category distribution of results.

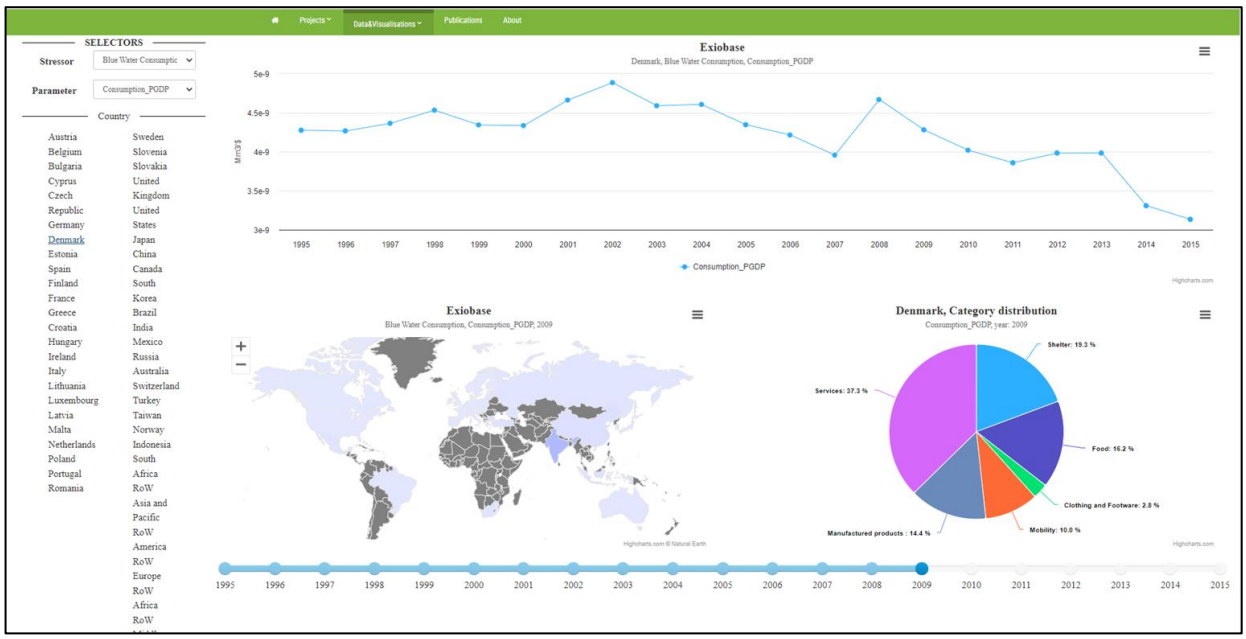

Figure 8 Environmental Footprints - EXIOBASE 3

The main objective of the tool is to provide materials for studies and analyses of global supply chains data based on MRIO tables and to calculate the environmental footprints of various countries and sectors. The tool is advanced and articulated in terms of the possible options available for the users to inspect. However, due to the enormous dimensions

of the database tables with which it is able to interact in real-time, given the user selections, the tool is often slow to respond to the user inputs or suffers from unexpected errors or blocks in the user experience. Moreover, the offered access to the database is free and unlimited but there are technical constraints on the number of data records downloaded per query and the number of possible queries per minute.

The JUST2CE DST should be easier in terms of databases handled as a trade-off for a fluid and flawless user experience via a clear and appealing visualization interface.

3.4. Ramascene

Ramascene [20] is a tool developed as the output of the EU project *RaMa-Scene: Raw Materials SCENario Efficiency improvement blended learning package and assessment tool*, through the co-funded EU program *EIT RawMaterials*, which ended in 2019. The tool was able to plot on a world map the results of a MRIO analysis performed on the EXIOBASE database, based on the user's input options in terms of countries, years, sectors and products, etc. The tool also offered the user the powerful possibility to apply changes to the EXIOBASE model used as a base, with the aim to investigate alternative scenarios of supply chains generated using user-custom models. Its features were vast and advanced, with a high degree of customization for the users, although it presented issues with slowness when performing the analyses, due to the huge size of database tables handled.

Since the tool was open source and its code was freely available to the technical and scientific community, in the preliminary design phase of the JUST2CE DST it was suggested that the to-be-developed tool could draw on Ramascene as the starting point to be further developed and adapted to the JUST2CE use cases and requirements. However, the integration of the already existing code was technically difficult, mainly due to the obsolescence of the versions of the coding libraries exploited, and eventually starting from June 2023 the tool itself and the project website are no longer running and accessible, which led to the definite abandonment of the approach initially planned for the JUST2CE DST.

Despite abandoning the idea of integration and further development of the Ramascene code, the concept of visualizing a supply chain selected by the used on a world map was kept and applied to the JUST2CE DST, albeit in a simplified form to meet the requirements of the project.

3.5. EJAtlas

The Global Environmental Justice Atlas (EJAtlas) [21] aims to collect social conflicts around environmental issues and present them on an interactive world map. It was developed and coordinated by a team of researchers and activists with the final aim to give prominence and importance to social issues by providing testimonies on injustices on the global scale.

Researchers and teachers exploit the platform to analyse the causes of environmental injustices to develop statistical and comparative evaluations on a large data source, published then as scientific material, and illustrate some of the concepts taught in relevant courses. Activists and Environmental Justice Organizations use the platform to make the injustices they are struggling with more visible, for networking and forming alliances with other movements of resistance, and for learning from similar case studies already shared. The EJAtlas also offers possible guidance for decision making processes for public institutions, and supports the identification of regional patterns of injustices that might lead political interventions to mitigate inequalities. Finally, the journalistic community takes benefit from the information and contacts made available by the platform on the global scale and can also tap on the network of environmental justice organizations and EJAtlas community for their interviews and documentary works.

The EJAtlas was analysed as an example of a centre of distribution of information related to injustice cases reported on a world map. A similar feature was also requested for the JUST2CE DST, although adapted and customized to the specific topics of interest of the project. Moreover, the DST has integrated some articles and information taken from the EJAtlas related to some cases reported on a subset of world countries.

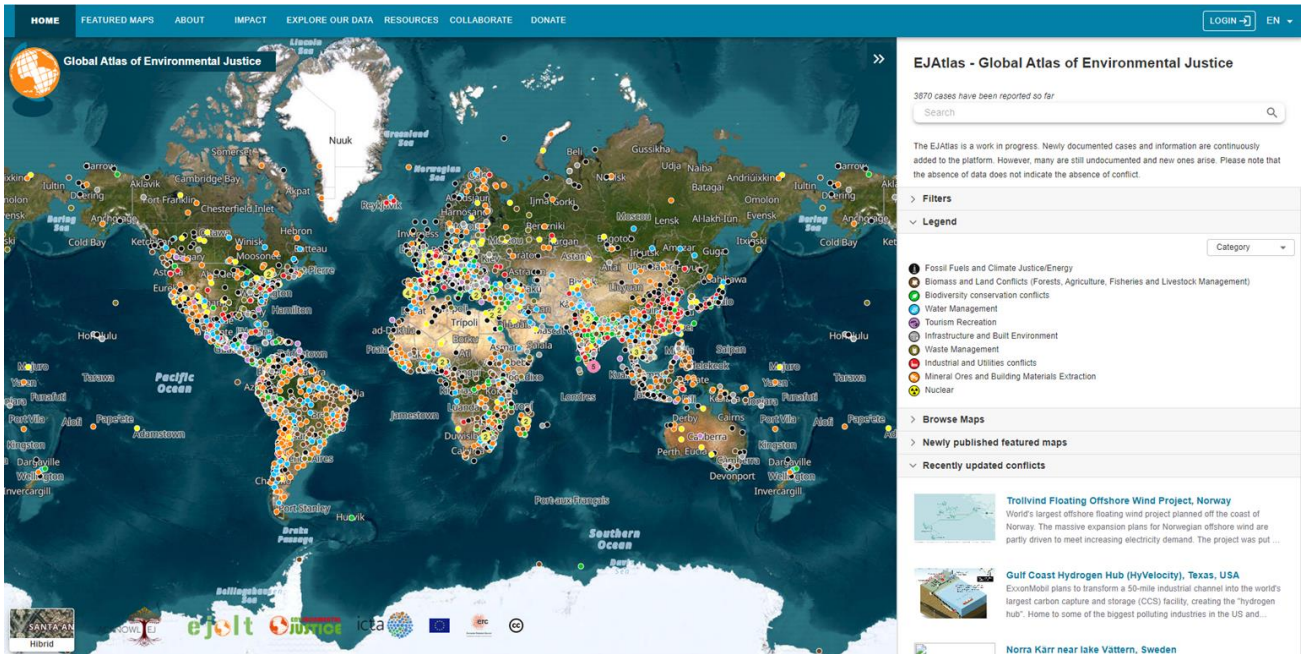

Figure 9 Global Atlas of Environmental Justice (EJAtlas)

4. DST design specifications and software architecture

The core feature of the JUST2CE DST is the capability to handle the EXIOBASE matrices based on the users' input and present the results plotted on a world map. Other complementary features of the tool include some advanced visualization options on a single country on the map, and two additional map layers related to the JUST2CE use cases and the integration of the Atlas from WP1. The tool is fully working and accessible on the web. Soon it will be integrated with the project's website by the partners in charge of the website to make the tool available to a wider audience interested in testing the tool. The DST was developed exploiting FastAPI framework [22] for the backend features, and React [23] for the frontend, using python and javascript as the main programming languages respectively.

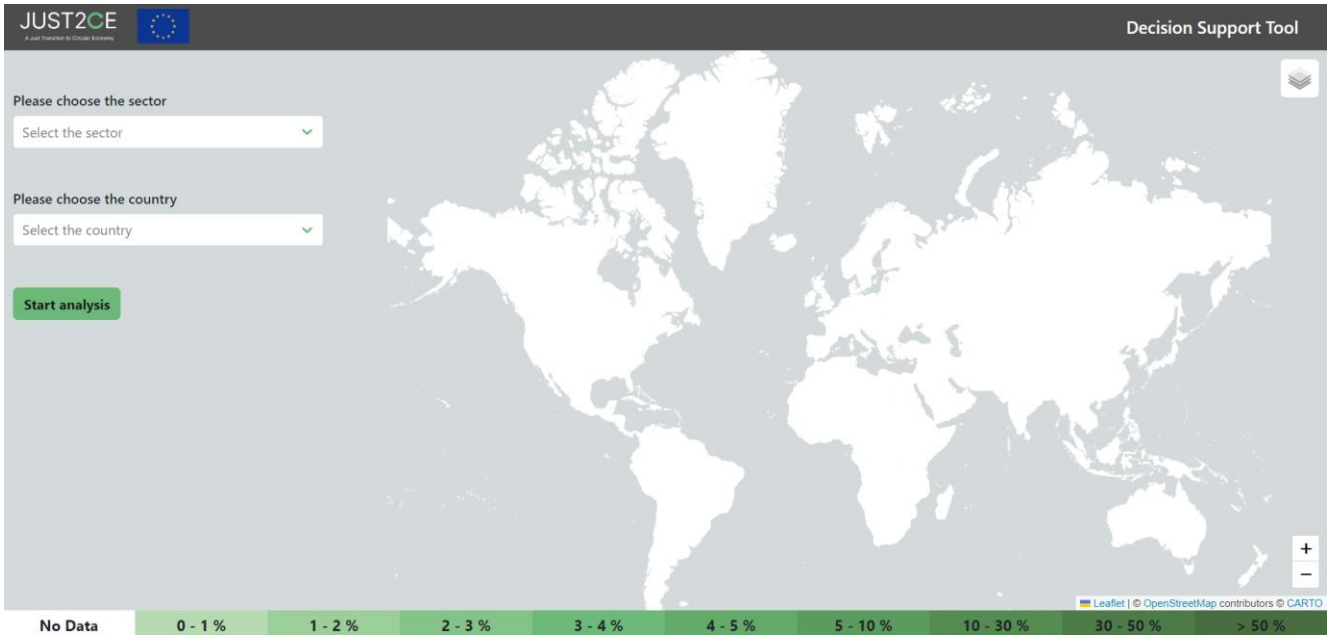

Figure 10 DST main dashboard

The first and essential point for the development of the JUST2CE DST was the definition of the macro-functionalities (MFs), in collaboration between E@W and USFD. The following subparagraphs describe the MFs from a more general perspective.

4.1. MF1: Typical Supply Chain Mapper tool

The most important feature of the DST is the representation of the EXIOBASE matrices on a world map. This macro-functionality also includes the user interface and menu, the supply chain map generation (and thus, the EXIOBASE matrices manipulation, further explained in the following paragraph), and the interactive map with popups and colours representing the results of the operations on the EXIOBASE data.

4.1.1. EXIOBASE matrices - Backend

The first step of the calculations is the parsing of the EXIOBASE matrices. To this aim, the python library pymrio [24] has been used, which is able to retrieve all the matrices in which we need to perform some of the mathematical formulae described above in Section 2.2. In particular the matrices A and Y are of key importance. The second step was

performing the operations to calculate the Leontief matrix and multiply it by the diagonalized vector f_d, extracted from the Y matrix on the basis of the country-sector selected by the user. The python libraries numpy [25] and pandas [26] were used to perform the matrix operations (the former) and transform the results into a dataframe easier to manage (the latter). The result is a series of numerical values for each sector (163) and each country (49), namely a 7987 x 7987 matrix. For visualization and validation purposes, the matrix has been saved and converted into an excel file that can be seen in Figure 11. The selection made by the user in the menu of the DST is used to select and extract the corresponding column of results to be then visualized on the world map.

		AT_Cultivation of paddy rice	AT_Cultivation of wheat	AT_Cultivation of cereal grains nec	AT_Cultivation of vegetables fruit nuts	AT_Cultivation of oil seeds	AT_Cultivation of sugar cane sugar beet	AT_Cultivation of plant based fibers	AT_Cultivation of crops nec	AT_Cattle farming	AT_Pigs farming	AT_Poultry farming	AT_Meat animals nec	AT_Animal products nec	AT_Raw milk	AT_Wool silk worm cocoons
AT	Cultivation of paddy rice	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AT	Cultivation of wheat	0	108,9687	0,0026	0,0244	0,0004	0,0002	0	0,0465	0,5162	1,1402	0,8177	0,0265	0,0167	0,2941	0
AT	Cultivation of cereal grains nec	0	0,0045	191,7575	0,063	0,0011	0,0006	0	0,1064	2,4564	6,9364	9,1555	0,0531	0,0412	3,2084	0,0001
AT	Cultivation of vegetables fruit nuts	0	0,0014	0,0021	1087,378	0,0003	0,0002	0	0,0011	0,3163	0,7819	0,5338	0,0039	0,0023	0,0497	0
AT	Cultivation of oil seeds	0	0,0006	0,0008	0,0066	40,9367	0,0001	0	0,0004	0,022	0,0541	0,0354	0,0001	0,0001	0,0041	0
AT	Cultivation of sugar cane sugar beet	0	0,012	0,0117	0,0672	0,0046	12,6159	0,0001	0,0068	0,1095	0,2228	0,1974	0,0101	0,0511	0,0255	0
AT	Cultivation of plant based fibers	0	0	0	0	0	0	0,0592	0	0	0	0	0	0	0	0
AT	Cultivation of crops nec	0	0,0023	0,0035	0,0231	0,002	0,0003	0	71,9037	0,0961	0,2667	6,2986	0,0418	0,0261	1,2801	0,0001
AT	Cattle farming	0	0,0028	0,0042	0,0284	0,0006	0,0003	0	0,0023	67,8556	0,6827	0,3181	0,0022	0,0045	0,0424	0,0001
AT	Pigs farming	0	0,0023	0,0034	0,0246	0,0005	0,0003	0	0,0019	0,2844	226,5248	0,4677	0,0008	0,0005	0,0404	0
AT	Poultry farming	0	0,0018	0,0026	0,0259	0,0005	0,0002	0	0,0014	0,099	0,2271	301,936	0,0004	0,0003	0,0148	0
AT	Meat animals nec	0	0,0011	0,0016	0,0106	0,0002	0,0001	0	0,0009	0,0246	0,0724	0,0936	41,4905	0,0004	0,0051	0
AT	Animal products nec	0	0,0008	0,0013	0,0083	0,0002	0,0001	0	0,0007	0,0147	0,0428	0,0546	0,0001	30,6785	0,0031	0
AT	Raw milk	0	0,0036	0,0054	0,0393	0,0008	0,0004	0	0,0029	0,9252	3,3762	2,1655	0,0117	0,0646	51,6698	0
AT	Wool silk worm cocoons	0	0	0	0	0	0	0	0	0	0	0	0	0	0,0001	0,0302
AT	Manure treatment conventional storage and land app	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AT	Manure treatment biogas storage and land applicatio	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AT	Forestry logging and related service activities 02	0	0,1089	0,1776	1,8573	0,0186	0,0106	0	0,1637	0,3427	0,4872	0,4225	0,0021	0,0015	0,0787	0
AT	Fishing operating of fish hatcheries and fish farms ser	0	0,0001	0,0001	0,0006	0	0	0	0	0,0043	0,0095	0,0069	0	0	0,0007	0
AT	Mining of coal and lignite extraction of peat 10	0	0,0001	0,0001	0,001	0	0	0	0,0001	0,0003	0,0004	0,0008	0	0	0,0001	0
AT	Extraction of crude petroleum and services related to	0	0,0528	0,0783	0,386	0,0095	0,0035	0	0,0675	0,0802	0,1073	0,1582	0,0016	0,0014	0,0179	0
AT	Extraction of natural gas and services related to natura	0	0,0164	0,0236	0,2155	0,0037	0,0018	0	0,0197	0,0426	0,0642	0,0919	0,0013	0,0011	0,01	0

Figure 11 Extract of the final matrix x, visualized as an excel table (USFD)

However, as can be seen in Figure 11, the extraction of the column corresponding to the user input is a list of 7987 values, which represent the 163 sectors repeated for each country. Moreover, most of the results are very small numbers, giving little to no meaningful information to the analysis of the typical supply chain.

It was therefore decided to aggregate the results for each country, meaning that the desired result would have been a matrix with 49 rows, summing the values of all sectors for each country. Moreover, the numerical values were normalized and rounded to the second decimal digit, as represented in the excel table replicated in Figure 12.

	AT Cultivation	AT Cultivation	AT Cultivation	AT Cultivation.	AT Cultivation	AT Cultivation	AT Cultivation	AT Cultivation	AT Cattle.farr	AT Pigs.farmi	AT Poultry.fa	AT Meat.anin	AT Animal.pro	AT Raw.milk
AT	-	137,67	235,35	1.428,72	47,53	16,13	0,06	96,34	140,94	368,43	437,56	43,27	32,29	75,45
BE	-	0,43	0,57	4,12	0,11	0,04	-	0,35	1,21	1,81	1,55	0,02	0,02	0,32
BG	-	0,16	0,10	0,69	0,05	0,01	-	0,05	0,17	0,30	0,25	0,00	0,00	0,04
CY	-	0,01	0,01	0,13	0,00	0,00	-	0,01	0,02	0,04	0,04	0,00	0,00	0,01
CZ	-	2,62	1,86	9,54	0,67	0,09	-	0,93	1,59	2,51	2,50	0,02	0,01	0,43
DE	-	7,66	11,10	44,62	1,26	0,43	-	7,65	24,82	30,18	25,31	0,16	0,12	6,50
DK	-	0,23	0,21	1,33	0,07	0,01	-	0,15	0,74	0,83	0,77	0,01	0,01	0,20
EE	-	0,02	0,03	0,20	0,01	0,00	-	0,02	0,04	0,08	0,07	0,00	0,00	0,01
ES	-	0,34	0,45	5,37	0,10	0,03	-	0,26	0,77	1,39	1,18	0,02	0,01	0,20
FI	-	0,11	0,15	0,87	0,03	0,01	-	0,08	0,21	0,33	0,29	0,00	0,00	0,06
FR	-	1,02	1,17	6,12	0,33	0,07	-	0,62	1,80	3,06	2,77	0,03	0,02	0,47
GR	-	0,09	0,12	0,88	0,02	0,01	-	0,06	0,19	0,41	0,33	0,00	0,00	0,05
HR	-	0,05	0,08	0,49	0,01	0,00	-	0,04	0,11	0,20	0,16	0,00	0,00	0,03
HU	-	1,33	1,34	4,81	0,28	0,04	-	0,85	1,22	2,02	1,97	0,01	0,01	0,41
IE	-	0,28	0,35	1,66	0,07	0,02	-	0,17	0,58	0,74	0,66	0,01	0,01	0,16
IT	-	1,33	2,02	13,55	0,27	0,10	-	1,17	3,74	5,86	4,65	0,03	0,02	0,91
LT	-	0,10	0,05	0,35	0,03	0,00	-	0,02	0,08	0,15	0,13	0,00	0,00	0,02
LU	-	0,07	0,10	0,56	0,02	0,01	-	0,05	0,12	0,19	0,17	0,00	0,00	0,03
LV	-	0,03	0,03	0,17	0,01	0,00	-	0,02	0,04	0,07	0,06	0,00	0,00	0,01
MT	-	0,01	0,02	0,10	0,00	0,00	-	0,01	0,02	0,03	0,03	0,00	0,00	0,00

Figure 12 Portion of the final x matrix aggregated by country (USFD)

With the aim to maximize the meaning of the results displayed on the map, all values inside the matrix have been subsequently converted to percentages, considering the impact of the relevant value (single country on the rows) on the global impact of the whole supply chain selected corresponding to the country-sector couple on the labels of each column (which is the sum of all values column-wise). The results of this final calculation are shown in Figure 13.

	AT	AT	AT	AT	AT	AT	AT	AT	AT	AT	AT	AT	AT	AT
	Cultivation	Cultivation	Cultivation	Cultivation	Cultivation	Cultivation	Cultivation	Cultivation	Cattle.farr	Pigs.farmir	Poultry.far	Meat.anim	Animal.pro	Raw.milk
AT	0,00%	77,13%	81,42%	86,77%	82,90%	86,13%	99,84%	76,28%	64,95%	78,69%	82,89%	98,21%	98,06%	78,76%
BE	0,00%	0,24%	0,20%	0,25%	0,19%	0,19%	0,00%	0,28%	0,56%	0,39%	0,29%	0,04%	0,05%	0,34%
BG	0,00%	0,09%	0,03%	0,04%	0,08%	0,03%	0,00%	0,04%	0,08%	0,06%	0,05%	0,00%	0,00%	0,04%
CY	0,00%	0,01%	0,01%	0,01%	0,01%	0,00%	0,00%	0,01%	0,01%	0,01%	0,01%	0,00%	0,00%	0,01%
CZ	0,00%	1,47%	0,64%	0,58%	1,16%	0,46%	0,00%	0,73%	0,73%	0,54%	0,47%	0,04%	0,04%	0,45%
DE	0,00%	4,29%	3,84%	2,71%	2,20%	2,31%	0,00%	6,06%	11,44%	6,45%	4,80%	0,37%	0,37%	6,79%
DK	0,00%	0,13%	0,07%	0,08%	0,12%	0,07%	0,00%	0,12%	0,34%	0,18%	0,15%	0,02%	0,02%	0,21%
EE	0,00%	0,01%	0,01%	0,01%	0,01%	0,01%	0,00%	0,01%	0,02%	0,02%	0,01%	0,00%	0,00%	0,01%
ES	0,00%	0,19%	0,16%	0,33%	0,17%	0,16%	0,00%	0,20%	0,36%	0,30%	0,22%	0,03%	0,04%	0,21%
FI	0,00%	0,06%	0,05%	0,05%	0,04%	0,05%	0,00%	0,07%	0,10%	0,07%	0,05%	0,01%	0,01%	0,06%
FR	0,00%	0,57%	0,40%	0,37%	0,57%	0,38%	0,00%	0,49%	0,83%	0,65%	0,52%	0,07%	0,08%	0,50%
GR	0,00%	0,05%	0,04%	0,05%	0,04%	0,04%	0,00%	0,05%	0,09%	0,09%	0,06%	0,00%	0,00%	0,05%
HR	0,00%	0,03%	0,03%	0,03%	0,02%	0,02%	0,00%	0,03%	0,05%	0,04%	0,03%	0,00%	0,00%	0,03%
HU	0,00%	0,75%	0,46%	0,29%	0,49%	0,21%	0,00%	0,67%	0,56%	0,43%	0,37%	0,03%	0,03%	0,43%
IE	0,00%	0,16%	0,12%	0,10%	0,12%	0,11%	0,00%	0,14%	0,27%	0,16%	0,13%	0,02%	0,02%	0,17%
IT	0,00%	0,75%	0,70%	0,82%	0,46%	0,52%	0,00%	0,92%	1,73%	1,25%	0,88%	0,07%	0,07%	0,95%
LT	0,00%	0,05%	0,02%	0,02%	0,05%	0,01%	0,00%	0,02%	0,04%	0,03%	0,02%	0,00%	0,00%	0,02%
LU	0,00%	0,04%	0,03%	0,03%	0,03%	0,03%	0,00%	0,04%	0,05%	0,04%	0,03%	0,00%	0,00%	0,03%
LV	0,00%	0,01%	0,01%	0,01%	0,01%	0,01%	0,00%	0,02%	0,02%	0,01%	0,01%	0,00%	0,00%	0,01%
MT	0,00%	0,01%	0,01%	0,01%	0,00%	0,01%	0,00%	0,01%	0,01%	0,01%	0,01%	0,00%	0,00%	0,01%
NL	0,00%	0,32%	0,18%	0,28%	0,30%	0,17%	0,00%	0,37%	2,02%	0,90%	0,67%	0,07%	0,07%	1,25%
PL	0,00%	0,65%	0,25%	0,31%	0,61%	0,23%	0,00%	0,30%	0,46%	0,41%	0,32%	0,03%	0,04%	0,26%
PT	0,00%	0,05%	0,04%	0,04%	0,04%	0,04%	0,00%	0,05%	0,07%	0,06%	0,05%	0,01%	0,01%	0,04%
RO	0,00%	0,86%	0,07%	0,26%	0,82%	0,06%	0,00%	0,08%	0,12%	0,10%	0,12%	0,01%	0,01%	0,08%
SE	0,00%	0,15%	0,12%	0,13%	0,11%	0,12%	0,00%	0,16%	0,23%	0,18%	0,14%	0,02%	0,02%	0,14%

Figure 13 Final structure of the aggregated x matrix (USFD)

In this way, it was finally possible to associate each country on the map with a single value expressed as a percentage, which was also used as the legend for colouring the countries according to their result.

As a further feature, the tool also calculates the impact of the single sectors on the total related to each country, meaning that the tool also performs the calculations comparing the two matrices (the original x matrix and the aggregated form). This allows the tool to identify and display the top 5 impacting sectors for each country.

Considering the complexity and the computational resources required, all these described operations are performed by FastAPI in the backend of the application once at every server startup. This was a design choice made in order to optimize the loading time, and not to freeze the user experience while the tool is in use. This is possible because the relevant matrices which were chosen for calculation are static and are no longer modified by other following operations.

The Data Transfer Object (DTO), populated by the backend of the tool and sent to the fronted, has the following structure:

```
class UserResponse(BaseModel):
    sector: str
    originCountry: str
    filtering: List[FilterObject] = Field(default=None)
```

```
    aggr_result: List[AggrSumObject] = Field(default=None)
    regional_csv: List[RegionalCsv] = Field(default=None)

class FilterObject(BaseModel):
    ISO_A2 : str
    sector : str
    result : float

class AggrSumObject(BaseModel):
    ISO_A2 : str
    aggr_result : float
    aggr_sum : float
    aggr_impact : float
```

The main object, the UserResponse, saves the sector and the country as selected by the user in the main dashboard. After the calculations already described, the model saves the results called `filtering` as a list of `FilterObject`, each one consisting in the ISO A2 code of the country, the sector and the related result. The `AggrSumObject` is used to save all the values required to perform the normalization of results on the total input – as described above and visualized in the excel files above.

The backend also performs another functionality of the DST that will be described deeper in the following paragraphs, which is the parsing of the online Google sheet referring to the Just Transition Layer of the map and linked to the related country on the map. The mentioned data is saved in the DTO as a list of the following objects, containing all the textual information corresponding to the columns of the Google sheet file:

```
class RegionalCsv(BaseModel):
    country : str
    iso: str
    gri : str
    gri_meta : str
    gri_weblink : str
    ejatlas_weblink : str
```

4.1.2. World Map Visualization - Frontend

The visualization of the EXIOBASE results plotted on a world map was selected as the primary visualization fashion, in coherence with the state-of-the-art analyses and the structure of EXIOBASE itself. The map is implemented using the React-Leaflet library [27], which makes Leaflet maps available to and compatible with React components as well.

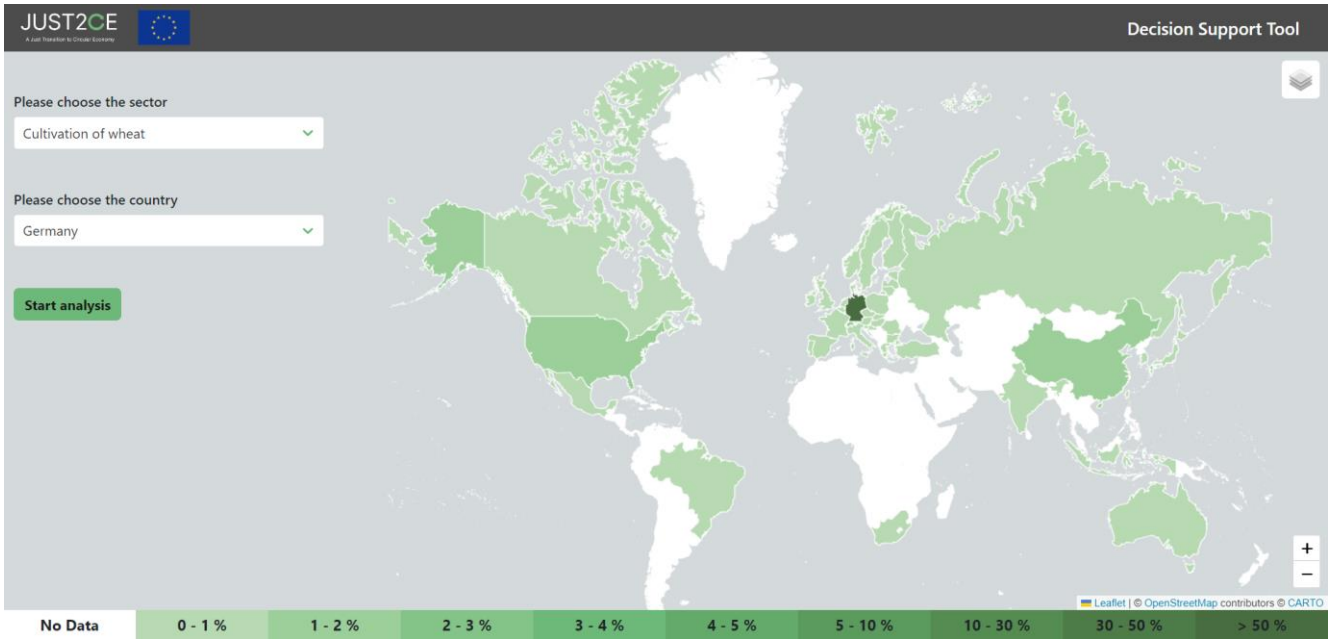

Figure 14 Dashboard of the DST displaying the map coloured based on the supply chain selected by the user

After the user clicks on the “Start analysis” button, the backend performs the required filtering on the EXIOBASE final demand matrix, and sends the resulting table to the frontend. Here, via dedicated javascript functions, each aggregated result is associated with the related country on the map on the basis of the ISO_A2 codes. Then, the map is reloaded and each country is coloured following the legend displayed below the map itself. This shading is performed on the basis of the percentage of the global input of that country on the selected supply chain, as described in Section 4.1.1.

The detailed information on the results of the EXIOBASE calculations are displayed in the popups that appear by clicking on a single country, as required. Each popup displays the global input of the clicked country, the top 5 impacting sectors on the input from that country, and the information related to the MF2 on the Just Transition overlay, described in Section 4.2 which follows.

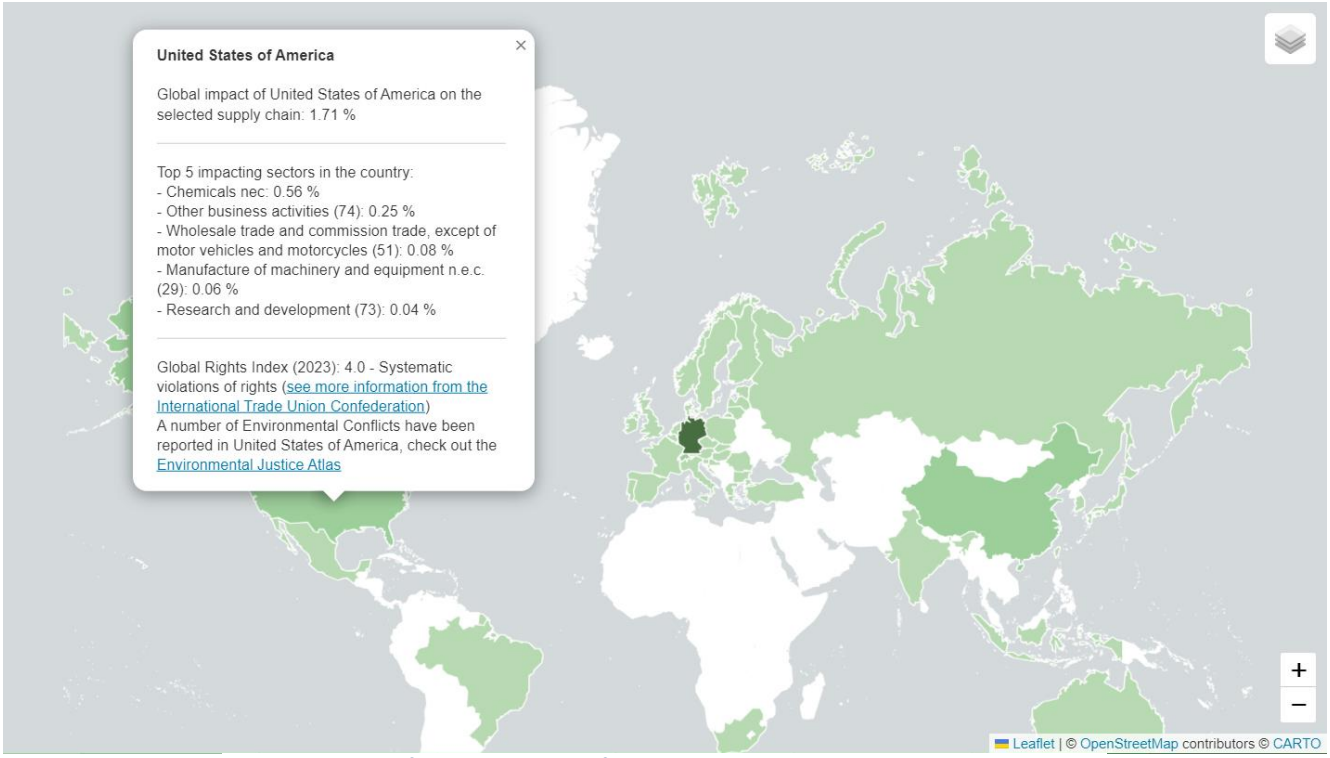

Figure 15 Detail of the map on the information displayed on a popup on each country

4.2. MF2: Just Transition Overlay

For the purposes of this macro-functionality specifically, a dedicated dataset has been created by the consortium partners that are experts on the just transition themes of the project, it can be found here. This dataset has been integrated into the DST as the main data source to display a Just Transition Overlay layer on the world map. This dataset is hosted as a shared and editable Google Sheet, which can be updated by the expert members of the consortium to reflect ongoing advancements and findings of parallel activities relevant also for the purposes of the DST. At the time of writing, the table contains information from the Global Rights Index and EJAtlas for each country listed, providing relevant justice dimensions for each country. A screenshot of the mentioned table is illustrated in Figure 16.

Country	ISO code	Global Rights Index	GRI Metadata	GRI Weblink	EJAtlas Weblink
Austria	AT	1	Sporadic violations of rights	https://www.globalrightsindex.org/en/2023/countries/aut	https://ejatlas.org/country/austria
Belgium	BE	3	Regular violations of rights	https://www.globalrightsindex.org/en/2023/countries/bel	https://ejatlas.org/country/belgium
Bulgaria	BG	3	Regular violations of rights	https://www.globalrightsindex.org/en/2023/countries/bgr	https://ejatlas.org/country/bulgaria
Cyprus	CY	N/A	No data		https://ejatlas.org/country/cyprus
Czechia	CZ	2	Repeated violations of rights	https://www.globalrightsindex.org/en/2023/countries/cze	https://ejatlas.org/country/czech-republic
Germany	DE	1	Sporadic violations of rights	https://www.globalrightsindex.org/en/2023/countries/deu	https://ejatlas.org/country/germany
Denmark	DK	1	Sporadic violations of rights	https://www.globalrightsindex.org/en/2023/countries/dnk	https://ejatlas.org/country/denmark
Estonia	EE	2	Repeated violations of rights	https://www.globalrightsindex.org/en/2023/countries/est	https://ejatlas.org/country/estonia
Spain	ES	2	Repeated violations of rights	https://www.globalrightsindex.org/en/2023/countries/esp	https://ejatlas.org/country/spain
Finland	FI	1	Sporadic violations of rights	https://www.globalrightsindex.org/en/2023/countries/fin	https://ejatlas.org/country/finland
France	FR	2	Repeated violations of rights	https://www.globalrightsindex.org/en/2023/countries/fra	https://ejatlas.org/country/france
Greece	GR	4	Systematic violations of rights	https://www.globalrightsindex.org/en/2023/countries/grc	https://ejatlas.org/country/greece
Croatia	HR	2	Repeated violations of rights	https://www.globalrightsindex.org/en/2023/countries/hrv	https://ejatlas.org/country/croatia
Hungary	HU	4	Systematic violations of rights	https://www.globalrightsindex.org/en/2023/countries/hun	https://ejatlas.org/country/hungary
Ireland	IE	1	Sporadic violations of rights	https://www.globalrightsindex.org/en/2023/countries/irl	https://ejatlas.org/country/ireland
Italy	IT	1	Sporadic violations of rights	https://www.globalrightsindex.org/en/2023/countries/ita	https://ejatlas.org/country/italy

Figure 16 Just Transition Country Dataset created by USFD

The DST is able to parse this document, including any live updates, manipulate the results and visualize the information of each country in the related popup, in a readable format developed by those who have produced the spreadsheet. The parsing of the document is automatic and in real-time, the tool is able to detect updates (i.e., a user adds a second row for the same country, a user deletes a row etc.), and updates the information displayed on the map accordingly.

4.3. Integration within the JUST2CE framework

As further features, two additional layers have been added to the world map, called “JUST2CE Case Studies” and “Just CE Practices of Interest”. It is possible to enable and/or disable the visualization of the two layers via the dedicated menu on the top right corner on the map, presented in Figure 17.

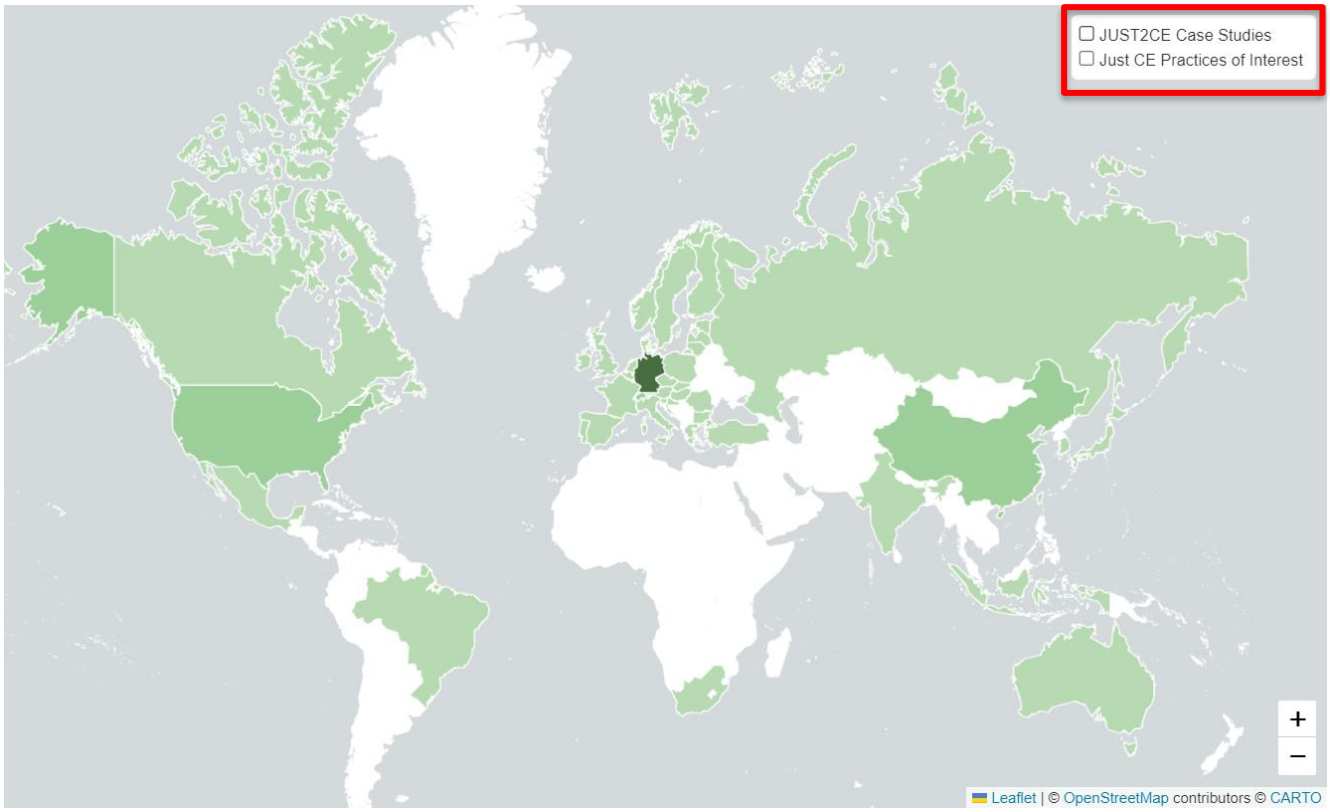

Figure 17 Detail of menu of the two additional map layers

As its name suggests, the “JUST2CE Case Studies” layer, presented in Figure 18, displays the markers placed on the countries where case studies have been investigated within WP2 of the project. By clicking on a marker icon, a popup is displayed to summarize some information related to the case study, including the country, the name, the sectors and the consortium partners involved. It also contains a link to the specific case study page on the project’s website, and for more detailed information.

Figure 18 JUST2CE Use Cases layer with detail of popup

The "Just CE Practices of Interest" layer, shown in Figure 19, displays markers corresponding to those found in the Atlas developed in the context of WP1 (Figure 20). The colours and the related legend used for the markers correspond to the ones used in the Atlas, and each marker, when clicked, displays some information including name, sectors, and the main circularity aspects taken from the Atlas.

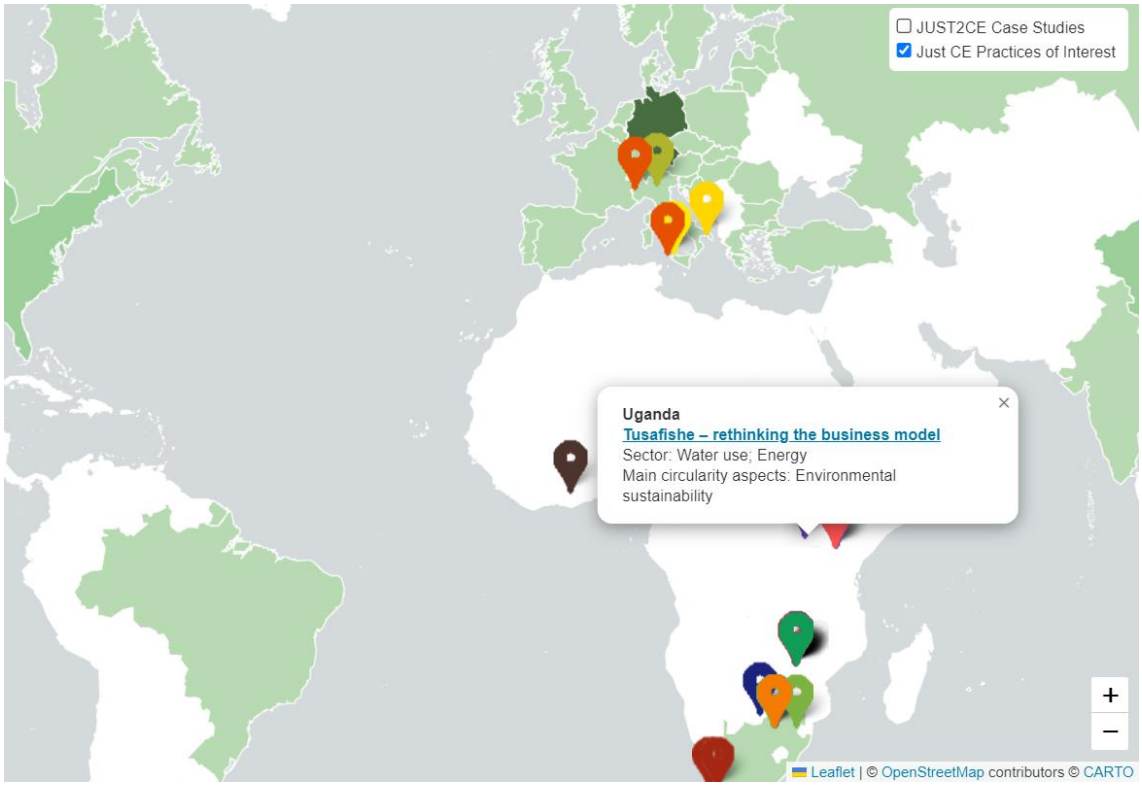

Figure 19 Just CE Practices of Interest (Atlas) with detail of popup

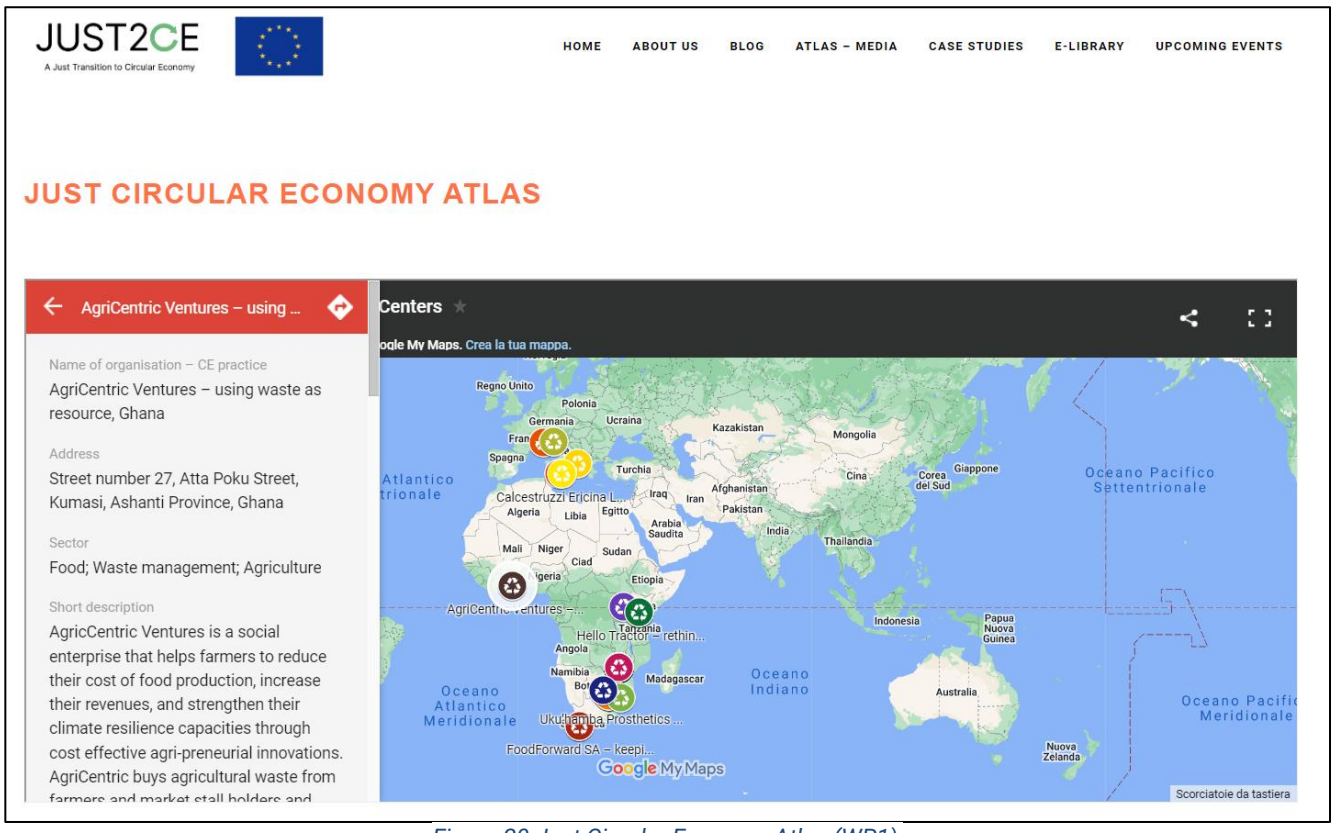

Figure 20 Just Circular Economy Atlas (WP1)

5. Conclusions and Future work

The features currently implemented in the DST act as a starting point for future improvements and further implementation. At the current stage, the DST can be considered as a knowledge exchange and learning tool, able to represent the consumption-based data on supply chains and match up such information with new experimental layers, which can give a geographical and quantitative dimension of the developed “just2ce indicators”. We intend these to be further built up based on methodologies and techniques being implemented in the project.

As a prototype version, the tool currently loads the EXIOBASE matrices related to 2022. Future developments may include other years of EXIOBASE and other MRIO databases, with the purpose to e.g. perform time comparisons, and results across databases, as well as present data from a wider range of countries and/or sectors. Furthermore, an integration of the production-based data accounted in EXIOBASE, along with the consumption-based one that is already implemented in the tool, might be added. The impact and satellite extension data in EXIOBASE might be added as well in the future, to investigate the impact of these stressors on the supply chains.

The Google sheet file for the Just Transition Country Dataset at the moment is public and contains a limited number of countries and information. In the future, it would be appropriate to store the file in a private directory, so that the permission of access and edit are restricted to authorized users, and thus develop an authentication mechanism to parse the file from the DST. It might be added the possibility for users to directly add information to the table and/or more markers on the different layers of the map via the tool, and in that case a dedicated authentication and authorization mechanism should be implemented.

Apart from these macro improvements, other minor improvements will be implemented thanks to the testing activities that will be carried out in other tasks of WP4, whose feedback will be used also for bug fixing and overall tool assessment. We expect the testing and dissemination phases of the tool, described in detail with D4.3 [28] to present additional avenues for further development and refinement of the tool.

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