MRIO analysis of CCS deployment of three selected promising regions

Release Status: FINAL

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Date: 24 March 2022

Filename and version: D4.4_MRIO_Analysis_ v2.1

Project ID NUMBER 837754

STRATEGY CCUS (H2020-LC-SC3-2018-2019-2020/H2020-LC-SC3-2018-NZE-CC)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 837754

Document History

Location

This document is stored in the following location:

Filename	D4.4_MRIO_Analysis_ v2.1
Location	website: https://www.strategyccus.eu/

Revision History

This document has been through the following revisions:

Version No.	Revision Date	Filename/Location stored:	Brief Summary of Changes
1	25/01/2022	Project share point	Writing improvements (by Helen Hund, Cecile Dumas, Patrícia Fortes and Paula Canteli)
2	24/03/2022	Project share point	Data update from WP5 on CAPEX and OPEX in the three selected regions (Table 2-2). This fact changes the quantitative results of the indicators all along the document presented in the previous version (tables and figures in sections 3 to 5 included), although only minor changes in the narrative appear. One additional paragraph clarifying the limitations of MRIOT has been included in section 2.1.1

Authorisation

This document requires the following approvals:

AUTHORISATION	Name	Signature	Date
WP Leader			DD/MM/YY
Project Coordinator	Fernanda de Mesquita Lobo Veloso		08/03/2022

For Deliverables, the Project Coordinator should receive the final version at least one week prior to the due date.

Distribution

This document has been distributed to:

Name	Title	Version Issued	Date of Issue
		PUBLIC	00/00/0000

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Cite this report as: Banacloche, S., Lechón, Y. 2022. Deliverable D4.4: MRIO analysis of CCS deployment of three selected promising regions in Europe. EU H2020 STRATEGY CCUS. Project 837754

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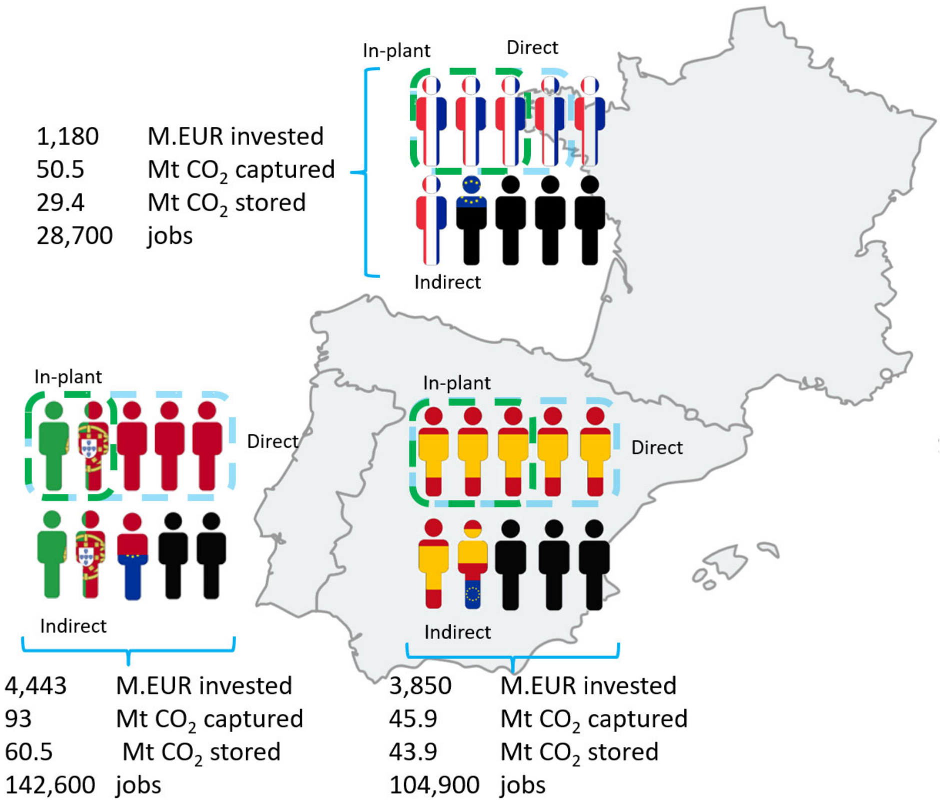
Executive summary

The main goal of D4.4 is to contemplate the socioeconomic benefits of CCS deployment in three selected promising regions: Ebro Basin in Spain, Lusitanian Basin in Portugal and Rhône Valley in France. Departing from the scenarios presented in WP5, in this document we estimate the value added and employment creation that would arise if the investments proposed do take place towards 2050.

This report explains the methodology used: the Multi-Regional Input-Output analysis that allows us to include both direct and indirect impacts that take place in the so-called global value chains. Hence, we present results regarding direct and indirect employment creation globally, identifying where (in which countries and sectors) these impacts are expected to be generated.

The results point out that more than 9,470 million euros (M.EUR henceforth, 2011 reference year) could be invested in CCS technologies during the period 2023-2050, contributing to capture almost 190 Mt CO_2 in the in aggregate. Part of the invested amount would be creating value added and employment outside the European Union, due to global value chains: intermediates produced upstream such as extractive activities and different kind of services. However, around 89% of the total investment in the three regions would be retained inside our borders. Altogether, CCS would create 276,200 full time equivalent (FTE) jobs up to year 2050, both direct and indirectly. That is approximately 11,050 permanent jobs. In Europe, the employment retained would be 203,300 FTE jobs (74%), or 8,130 permanent jobs. The rest is generated outside the European Union.



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1 Introduction

The COP26 took place in Glasgow last November 2021. The Second Draft to be signed by the parties included the commitment to accelerate the "phaseout of unabated coal power" (Kottasová et al., 2021), meaning that countries could continue to use coal if they are able to capture the emissions from it. This is just another example of the urgent need to deploy CCUS technologies in the short-term to fight against Climate Change. According to a recent work from Greig and Uden focusing on the United States, they indicate that getting to net-zero emissions (NZE) without CCUS is costlier, more difficult, and likely not possible in at least some major economies, without breakthrough advances in mitigating hard-to-abate sectors and/or natural climate solutions (Greig and Uden, 2021).

All along the Strategy CCUS Project, the need for carbon capture, utilization and storage technologies has been stressed as essential to reach carbon neutrality, in a context marked by the Paris Agreement and the net-zero emissions ambitions in Europe. These technologies are mature and available, with considerable real-world experience, but their deployment is still limited (Peridas and Schmidt, 2021). Although not energetically effective when retrofitted or installed in fossil fuel plants when compared to renewables plus storage (Sgouridis et al., 2019), CCS technologies are required and indispensable for other carbon and energy intensive industrial activities with no current cleaner substitutes (hard-to-abate industries). Its success not only depends on technological advances but also on political willingness and social acceptance (Jiang et al., 2022). Therefore, efforts need to be put so that CCUS worldwide coordination is strengthened and rapid changes in policy take place (Martin-Roberts et al., 2022).

However, political and economic barriers regarding investment incentives, financial commitment, socioeconomic priorities, and the lack of regulatory and policy frameworks hinder the deployment of CCUS worldwide (Banacloche et al, 2022). The aforementioned limiting factors induce problems related to complexity in the deployment, expensive and energy-intensive processes (Lipponen et al., 2017). WP4 "Mapping environmental and economic drivers" undertakes environmental and cost estimates to ensure CCUS is sustainable. A wide-used methodology to address the environmental impacts of these investments is the Life Cycle Assessment (LCA) methodology (Stamford and Azapagic, 2014), performed in Deliverable 4.3. In the present document, we focus on CCS stages. It is usually argued that CCS technologies are cross-sector, large spatial scale, long duration and high investment risk technologies (Wang and Qie, 2018), which added to the uncertainty of payoff given the price volatility of carbon prices, makes them unattractive to reach a large-scale commercial use. However, the aim of this report, aligned with the Consortium, is to encourage CCS deployment by providing useful insights about its attractiveness to policy makers.

Literature about CCS from a sustainability perspective is focused mainly in 1) the development of CCS technologies (feasibility, costs, roadmap, timing); 2) cost estimation of power generation after

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CCS adoption (techno-economic performance); and 3) Effects on GHG reduction (Shin et al., 2016). Having tackled these topics in other deliverables, the purpose of this report is to focus on the socioeconomic impacts of CCS deployment in the three previously selected (WP2) promising European regions. To this respect, literature is scarcer, but existent. Some research points out the employment intensity of CCS activities when compared to other renewable power sectors (Jiang et al., 2019; Koelbl et al., 2015) and the employment creation in Europe, considering economic growth through new net-zero industries and innovation spillovers (Townsend et al., 2020). Apart from the techno-economic assessment of Deliverable 4.5, it is valuable to also consider socioeconomic aspects as those mentioned above. In this sense, this report relies on the input-output analysis, usually applied to assess energy investments and employment creation (Jenniches, 2018; Cameron and van der Zwaan, 2015; Markaki et al., 2013), including carbon capture (Jiang et al., 2019). In an intertwined world, production is determined by the so-called global value chains (GVC), where intermediates cross borders to create final goods and services for consumption (Antràs and Chor, 2021). The main strength of the multi-regional input-output (MRIO) approach is its ability to capture the total impacts, direct and indirect, resulting from fragmented production processes all around the world. We combine input-output analysis with specific cost data on CCS activities settled by the Consortium.

Departing from the scenarios proposed in WP5 “Establishing the detailed plans for CCUS at different time-scales”, we contribute to shed light onto the role of CCS technologies on economic growth and job creation in Europe, by evaluating the socioeconomic effects (value added and employment) regarding the required investments to enable carbon capture, storage and utilization technologies in the Ebro Basin, the Lusitanian Basin, and the Rhône Valley up to 2050. The jobs and the value added associated with standard industries (without CCS) is excluded: here we will provide additional (new) jobs and value added creation, on the basis of existing plants and industries that “retrofit” to include capture modules. Hence, we can consider new impacts when compared with the absence of CCS. We are consistent with data provided by WP5 colleagues, assuming both their outputs and scenarios as our inputs to perform the input-output analysis (Berenblyum et al., 2021; Coussy, 2021). Following the Consortium indications and along with Tool 5.1 (economic simulation) data regarding the use of CO_2, this stage is excluded from the present document, due to the high degree of uncertainty and the potentials of different applications for the next decades to come.

Section 2 covers the methods and data used for the estimations of value added and employment creation. Results for the Ebro Basin, the Lusitanian Basin and the Rhône Valley are respectively presented in sections 3, 4 and 5. This research concludes in Section 6 with final comments and policy remarks.

2 Methods and data

The investments needed to implement CCS technologies will impact the economy of the regions contributing to value added generation and gross domestic product (GDP) growth as well as creating opportunities for employment. The Input-Output (IO) methodology is a tool that gathers information in a systematic way about the productive relations between the different sectors in any given country or regional economy. An IO table contains the inputs provided from each sector to the rest of the economy sectors. Using this information, it is possible to describe the interdependencies between production sectors and countries. Extensions of the methodology exist to simultaneously assess direct and indirect effects on some socioeconomic indicators, in particular job creation. Production processes increasingly fragment across borders, and this fundamentally alters the nature of international trade with deep consequences for the location of production as well as its impacts. Therefore, the proposed approach is to use a multiregional IO (MRIO) modelling that analyzes the consequences of this fragmentation in a comprehensive way identifying the sectors and regions that will be most stimulated by the investments needed to implement CCS technologies. We simulate how an exogenous increase on final demand, driven by the CCS investments, boosts economic growth and employment, capturing total effects (direct and indirect) including Global Value Chains phenomenon. We thus can identify the country and sector-origin of the impacts assessed. The basis of the MRIO modelling will be EXIOBASE, a global, detailed Multi-regional Environmentally Extended Supply and Use / Input Output (MR EE SUT/IOT) database: https://www.exiobase.eu/. The methodological principle a well as required data are summarized in Figure 2-1.

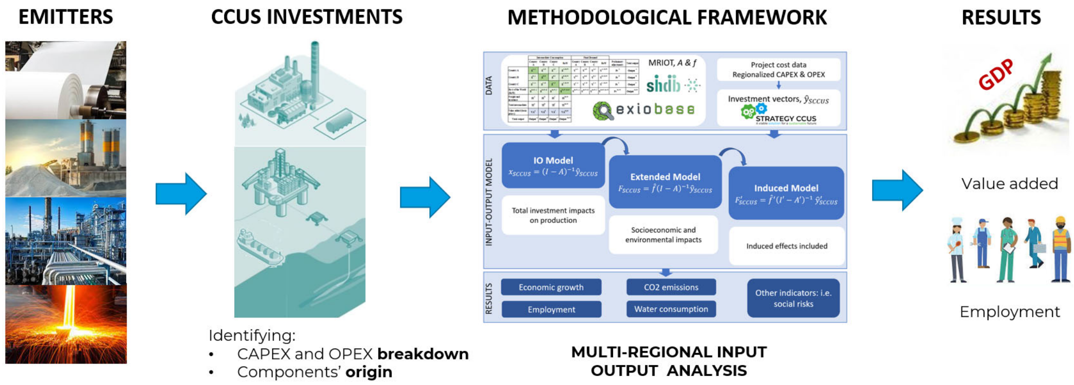

Figure 2-1 Methods and data

This analysis uses the data on costs collected in Task 5.2 (Economic Evaluation Regional scenarios) to construct the technology costs vectors. Afterwards, using the MRIO modelling framework, the effects on direct and indirect value-added generation and job creation are assessed, locating the sectors and countries where these effects are more relevant. This analysis is performed for three of the selected pilots in the most promising regions (see

Table 2-1). These scenarios from WP5 are possible paths (among others) of how greenhouse gas (GHG) emission reduction targets can be achieved with CO_2 capture, use and storage in the different regions. None of the industrial sites cited has committed at this stage to implement the scenarios

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presented here. These regional CCS scenarios are strongly linked to the 2050 national CO_2 reduction targets and to the national energy policies in place in each region (Coussy, 2021).

Table 2-1 Parameters included in the analysis

Socioeconomic Assessment	
Regions	Ebro Basin (ES), Lusitanian Basin (PT), Rhône Valley (FR)
Year	2050
Stages	Capture, Transportation and Storage
Impacts	Domestic, European, Rest of the world
Effects	Direct and Total
Indicators	Value added (M.EUR), Employment (1000p)

2.1 EMRIO model

We use a MRIO model to quantify the impacts of carbon capture, transportation, and storage investments. This model captures the intersectoral linkages (sales and purchases of intermediates) between sectors and countries, including international trade (Miller and Blair, 2009). The fundamental equation (1) shows how production is boosted by an exogenous final demand through the multiplier:

$$x = (I - A)^{-1}\, y \qquad (1)$$

Where x is the total production of goods and services, $(I - A)^{-1}$ is the inverse of Leontief, that considers all the direct and indirect requirements per unit of output needed to satisfy the final demand y. Instead of considering the final demand, we depart from WP5 specific cost data in Deliverable D5.3 (CCS-related components and services required for the construction, installation, operation, and maintenance stages) to adapt CCS investments on a MRIO basis format. Hence, we can use the Leontief's inverse to quantify the total effects, both direct and indirect, that CCS deployment would have for the three regions considered. Since our goal is to perform an assessment focused on value added and employment creation, the model has been extended (EMRIO) as seen below:

$$F = \hat{f}(I - A)^{-1}\hat{y}_{CCS} = P y_{CCS} \qquad (2)$$

Where F provides the total effects of the socioeconomic indicator considered (value added or employment), $\hat{f}$ is the socioeconomic diagonalized impact factor, and $\hat{y}_{CCS}$ are the diagonalized investments, for each CCS stage (see

Table 2-1). Direct impacts include the purchase of the components needed as initial investments to satisfy the demand for carbon capture equipment, transportation, and storage (i.e., direct employment in the supply of equipment, the installation and construction services), as well as the in-plant effects (i.e., operation and maintenance labour). Indirect effects refer to the intermediate inputs that, round by round of the production supply chain, were needed to provide the final components (Jenniches, 2018). When pre-multiplied by the Leontief inverse, P becomes the impact

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factor multiplier, capturing the direct and indirect impacts embodied in the supply chains (Banacloche, et al., 2022). The following matrix equation exemplifies where value added and employment from the whole CCS investments are created, considering three regions:

$$F = \begin{pmatrix} F^{11} & F^{12} & F^{13} \\ F^{21} & F^{22} & F^{23} \\ F^{31} & F^{32} & F^{33} \end{pmatrix} = \begin{pmatrix} P^{11} & P^{12} & P^{13} \\ P^{21} & P^{22} & P^{23} \\ P^{31} & P^{32} & P^{33} \end{pmatrix} \begin{pmatrix} y^{11}_{CCS} \\ y^{21}_{CCS} \\ y^{31}_{CCS} \end{pmatrix} = \begin{pmatrix} P^{11}y^{11}_{CCS} + P^{12}y^{21}_{CCS} + P^{13}y^{31}_{CCS} \\ P^{21}y^{11}_{CCS} + P^{22}y^{21}_{CCS} + P^{23}y^{31}_{CCS} \\ P^{31}y^{11}_{CCS} + P^{32}y^{21}_{CCS} + P^{33}y^{31}_{CCS} \end{pmatrix} \quad (3)$$

Where the superscripts (first and second) identify the source and destination of the impacts, respectively. Here the three regions are illustrative, and the example is applied for one host country of the investments (i.e., Spain, for the Ebro Basin). Since the host country of the CCS investments is just Spain (country 1 in the example), the vector y_{CCS} does not consider other destinations than country 1. Here, two main impacts are displayed: domestic impacts that are originated in Spain ($P^{11}y^{11}_{CCS} + P^{12}y^{21}_{CCS} + P^{13}y^{31}_{CCS}$ in Eq. 3), and total foreign impacts associated to the global supply chains that are originated in the rest of the countries ($P^{21}y^{11}_{CCS} + P^{22}y^{21}_{CCS} + P^{23}y^{31}_{CCS}$ for those coming from country 2 and $P^{31}y^{11}_{CCS} + P^{32}y^{21}_{CCS} + P^{33}y^{31}_{CCS}$ sourced in country 3). Some impacts are not related to the components and services, but those related to the use of factors of production required in-plant such as labour. These direct requirements are exogenously added to the impact calculation.

2.2 Data sources

2.2.1 Extended Multiregional Input-output Table

EXIOBASE3 is the chosen IO database in the present research. This MRIO database considers 49 regions and 163 industries, covering the period 1995–2011 (Stadler et al., 2018). Although there are other IO databases with more recent years, the extensive sectorial disaggregation of EXIOBASE makes this database the most suitable for the research to our understanding.

We use the latest year available (2011) and aggregate the whole set to 3 regions: the selected region (Ebro Basin, Lusitanian Basin and Rhône Valley, respectively), the European Union, and rest of the world. Two socioeconomic indicators have been chosen (see

Table 2-1): value added and employment. Value added corresponds to the overall factor payments' (labor and capital, land, net taxes on production, and remaining net operating surplus) country of origin.

One limitation of this methodology is that MRIOT takes into account countries, not regions. Therefore, we have to assume that the productive interlinkages of the Ebro Basin, the Lusitanian Basin and the Rhône Valley are similar to those of Spain, Portugal and France, respectively. That is, regional sectors involved behave the same as the national ones, requiring the same inputs per unit of output (both domestic and imported). In other words, the distinctions between intraregional and interregional linkages are not captured. Only in-plant indicators are closer to the effects that would occur in the three selected regions. On the contrary, impacts in global value chains (direct and indirect) are subjugated to the similarities that each region shares with its respective country. Hence, results must be understood as approximations.

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2.2.2 Specific cost data

Specific cost data depart from consortium data collected in Tool 5.1 and scenarios for Spain (Ebro Basin), Portugal (Lusitanian Basin) and France (Rhône Valley) provided in Deliverable 5.2 (Business Cases). In particular, data is obtained from the summary of cost calculated in different excel sheets: capture, storage, transport and utilization (SUMMARY-L3, Capture-L2, Storage-L2, Transport-L2 and Utilisation-L2 sheets included in Level_2_3_WP5.1_StrategyCCUS_3.xlsx of Tool 5.1). We look for the overall CAPEX and OPEX to be installed up to 2050 by all the emitter industries considered. Here, all information required is gathered in a compiled and efficient format: both CAPEX and OPEX of every stage are discounted to bring the cash flows to present values (2021 reference year). Also, a learning factor cost reduction of 1% is applied for all cost except for shipping-transport, which is maintained on 5% (Berenblyum et al., 2021). Hence, only the inflation rate remains necessary to adapt current prices to MRIO table prices (2011 reference year). With respect to the OPEX, we calculate the FIXOM and VAROM from Capture – L2 totals (in percentages). Since the other stages do not make this differentiation, we maintain the OPEX without further disaggregation.

Since different scenarios have been elaborated in WP5, here we present one scenario per selected region, suggested by WP5 colleagues as the most feasible, relevant or appealing, in each case. For the Ebro Basin region, we consider the alternative scenario for 2050. For the Lusitanian Basin, also an alternative scenario with offshore storage has been selected. Finally, for the Rhône Valley, the main scenario is assessed. In the present document we cover the entire carbon capture and storage process (value chains included). We present the following calculations:

- **In-plant impacts**: direct impacts related to compensation of employees (value added, considered as induced effects in the sector allocation, please see 2.3.1 section) and number of jobs. For the later, we take the average salary provided in deliverable 5.2 for each analysed region and take the compensation of employees. These impacts are located in the host country and are mostly related to the functioning and maintenance of the technology.
- **Global value chain (GVC) impacts**: both direct and indirect impacts related to the fragmentation of production in successive rounds of production until the goods and services required to deploy CCS technologies are completed (final goods). They happen inside the host country, as well as in Europe and the rest of the world, and depend on the industrial linkages among countries and sectors.

We leave the ripple effects from capital and labour excluded from the analysis. These so-called induced effects would create an additional stimulus in the economy. However, it is out of the scope of the present analysis.

2.3 CCS investments modelling

For the adaptation of specific cost data into the MRIO investments, the next arrangements have been performed. The first one is to bring the data from Tool 5.1 to the MRIO table reference year (2011). The inflation rate is obtained as an average of 2020 looking at the 1.1.3. HICP - Industrial goods excluding energy (Euro Area) (ECB, 2020). Table 2-2 below shows input data for the three selected regions.

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Table 2-2 Input data for the MRIO analysis

Data for 2050 (2011 reference year)		Ebro Basin	Lusitanian Basin	Rhône Valley
CAPEX, M.EUR	Capture	560.4	1400.6	224.6
	Transport	235.1	130.9	39.0
	Storage	38.4	127.8	86.9
	Total (disc.)	833.9	1659.4	350.6
OPEX, M.EUR	Capture	1770.9	2341.6	505.4
	Transport	1099.4	77.3	160.5
	Storage	148.7	364.7	163.5
	Total (disc.)	3019.8	2783.6	829.4

2.3.1 Capture Stage

Once data regarding aggregate CAPEX and OPEX is suitable for the MRIO table, the next step consists in creating an investment vector that decomposes the CAPEX and OPEX into the components and services required to deploy the technology. Finally, disaggregated data on components has to be allocated in the sector basis format of the MRIO table. As an example: the *absorber (scrubber)* required in the capture stage (where CO_2 is bound to the amines while the exhaust gas is released) is included in the *Manufacture of machinery and equipment n.e.c. (29)* sector (see Table 2-3).

Although capture can be seen as modular somehow (Carbon8, 2018), adding carbon capture usually may affect not only to the additional infrastructure but also the need to change other components in the power plant. Thereby it is not strictly modular (James III, R.E., et al., 2019). Additional costs may arise not only due to the capture process itself (i.e., the power to operate the capture module) but also in the configuration of the industry's main activity: curiously, some costs can be reduced with capture (i.e., the steam turbine generator for electricity production becomes cheaper in a new-built power plant with capture) (James III, R.E., et al., 2019). One first consideration here is assuming carbon capture as a **modular technology**, in the sense that equipment can be installed in whatever industry and without interfering with the main activity. Thus, we assume modularity in capture for the main group of components and related services, namely: the compressor, absorber, cooler, heat exchanger, striper (including reboiler) condenser and amine pumps, among others. We consider a post-combustion process in all cases, being the predominant option for capturing CO_2 (Araújo and de Medeiros, 2017). The next step is to precisely describing these components and allocating them into the MRIO table format (both sector and country allocation).

For **sector allocation**, we have homogenised the components and services to standardize the process and make it somehow. The main flaw could be the loss of information. However, due to the macro-perspective of MRIO analysis, the own methodology provides a trade-off between detail loss and completeness. When aggregating to a sector basis, we already are assuming that sectors are representative, which might not be the case. However, this methodology is accepted by its virtues regarding the measurement of total (both direct and indirect) effects, despite the loss of detail. Both the components breakdown and sector allocation have been validated by the Consortium as

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acceptable. The components breakdown has been created from the basis of three main sources (Barker et al., 2009, James III, R.E., et al., 2019; World Bank, 2016) and WP4 indications.

Most of the references that include cost descriptions on carbon capture technology into components, equipment and services, are related to the power sector. Hence, searching for different configurations (like suitable for refineries, cement, iron and steel and chemical industries) is difficult (Leeson et al., 2017). Even harder is to find a complete decomposition of these costs. This is why we have assumed two types of components breakdown: those for power plants and those for industries (mostly based on cement plants).

We pay special attention to both heat for capture (MEA regeneration) and power for compression. In the first case, according to WP5, the steam is outsourced, so that no boiler with natural gas is installed. Instead, steam is purchased as a service. Regarding the power for compression, it is not included in the CAPEX at this stage, but in the transport stage. Therefore, we assume that the additional energy is supplied from the grid instead of being internalized by adding an energy block.

Here we do not consider the effects that these costs have on the main product (electricity or industrial products, depending on the emitter's activity). For example, the retrofitting of power plants alters their net electricity outputs, which raises the costs to maintain a constant electricity production. That is why we treat the capture stage as modular, in the sense that we just want to measure the impacts coming from the capture module alone, independently on the consequences it has on the main production of the emitter. Table 2-3 provides a cost breakdown regarding capture stage.

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Table 2-3 Capture Stage cost breakdown

Emitter	Cost breakdown	Participation	Sector allocation (EXIOBASE)
Power plant	**CAPEX**	100.0%	
	Equipment	42.6%	Manufacture of machinery and equipment n.e.c. (29)
	Separation unit (stripper)/Desorber		
	Absorber (scrubber)		
	Flue gas cooler/Cooler		
	CO_2 Compressor		
	Flue gas desulphurization		
	Heat exchangers		
	Reboiler		
	Facilities	49.7%	
	Instrumentation and control (computers and office equipments)	0.5%	Manufacture of office machinery and computers (30)
	Instrumentation and control (electrical equipment)	3.7%	Manufacture of electrical machinery and apparatus n.e.c. (31)
	Building and Structure	17.6%	Construction (45)
	Home office costs (incl. Insurance)	2.2%	Insurance and pension funding, except compulsory social security (66)
	Duct work	1.5%	Manufacture of fabricated metal products, except machinery and equipment (28)
	EPC services (design and engineering costs)	20.0%	Research and development (73)
	Other costs including temporary facilities, training, commissioning, start-up costs and spare parts	4.1%	Education (80)
		7.8%	
	HRSG, Ducktwork & Stack (for Power plants)	*1.9%*	Manufacture of office machinery and computers (30)
	Duct work	*0.5%*	Manufacture of fabricated metal products, except machinery

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			and equipment (28)
	Building and Structures/Improvements to the site	*5.4%*	Construction (45)
	OPEX		
	FIXOM	100.0%	
	Miscellaneous Maintenance Materials (machinery)	6.5%	Manufacture of machinery and equipment n.e.c. (29)
	Miscellaneous Maintenance Materials (electrical)	6.5%	Manufacture of electrical machinery and apparatus n.e.c. (31)
	Miscellaneous Maintenance Materials (construction)	6.5%	Construction (45)
	Insurance	37.9%	Insurance and pension funding, except compulsory social security (66)
	Maintenance Labour	33.8%	In-plant effects
	Operation Labour	8.9%	In-plant effects
	VAROM	100.0%	
	Water (process water and cooling water)/steam	6.2%	Steam and hot water supply
	Makeup and waste water treatment chemicals	5.4%	Waste water treatment, other
	Ammonia	9.5%	Chemicals nec
	CO_2 capture system chemicals (NaOH and Cansolv Solvent/Monoethanolamine -MEA-)	13.6%	Chemicals nec
	Other chemicals (i.e. Triethylene glycol, Brominated Activated Carbon)	2.8%	Chemicals nec
	Catalyst for SCR	1.1%	Chemicals nec
	Limestone, enhanced hydrated lime	11.4%	Manufacture of cement, lime and plaster
	Waste disposal	15.0%	Landfill of waste: Inert/metal/hazardous
	Miscellaneous materials	35.0%	Manufacture of machinery and equipment n.e.c. (29)
Industry	**CAPEX**	100.0%	
	Equipment	21.1%	Manufacture of machinery and equipment n.e.c. (29)
	Separation unit (stripper)/Desorber		

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	Absorber (scrubber)		
	Flue gas cooler/Cooler		
	CO_2 Compressor		
	Flue gas desulphurization		
	Heat exchangers		
	Reboiler		
	Facilities	54.9%	
	Instrumentation and control (computers and office equipment)	1.3%	Manufacture of office machinery and computers (30)
	Instrumentation and control (electrical equipment)	1.3%	Manufacture of electrical machinery and apparatus n.e.c. (31)
	Building and Structure	11.5%	Construction (45)
	Home office costs (incl. Insurance)	6.9%	Insurance and pension funding, except compulsory social security (66)
	Duct work	9.9%	Manufacture of fabricated metal products, except machinery and equipment (28)
	EPC services (design and engineering costs)	20.0%	Research and development (73)
	Other costs including temporary facilities, training, commissioning, start-up costs and spare parts	4.1%	Education (80)
		24.0%	
	Accessory electric plant (CHP plant): Electrical foundations	2.2%	Manufacture of electrical machinery and apparatus n.e.c. (31)
	Accessory electric plant (CHP plant): power transformers	9.5%	Manufacture of machinery and equipment n.e.c. (29)
	Duct work	5.5%	Manufacture of fabricated metal products, except machinery and equipment (28)
	Building and Structures / Improvements to site	5.2%	Construction (45)
	Selective Catalytic Reduction (SCR)	1.6%	Chemicals nec
	OPEX		
	FIXOM	100.0%	

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	Miscellaneous Maintenance Materials (machinery)	9.0%	Manufacture of machinery and equipment n.e.c. (29)
	Miscellaneous Maintenance Materials (electrical)	9.0%	Manufacture of electrical machinery and apparatus n.e.c. (31)
	Miscellaneous Maintenance Materials (construction)	9.0%	Construction (45)
	Insurance	18.8%	Insurance and pension funding, except compulsory social security (66)
	Maintenance Labour	36.8%	In-plant effects
	Operation Labour	17.4%	In-plant effects
	VAROM	100.0%	
	Water (process water and cooling water)/steam	0.3%	Steam and hot water supply
	Ammonia	1.1%	Chemicals nec
	Monoethanolamine (MEA)	7.6%	Chemicals nec
	Coal for CHP	45.9%	Production of electricity by coal
	Power (post combustion plant): Natural gas	39.1%	Production of electricity by gas
	Miscellaneous materials	2.2%	Manufacture of machinery and equipment n.e.c. (29)
	Catalyst for SCR	3.7%	Chemicals nec

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Regarding the **country allocation** of the capture stage inputs required, to define whether each region is autonomous in supplying the capture technology (the main components and equipment, installation, operation, and maintenance), we have assumed that in the near future, each region would have the potential to meet the needs of carbon capture deployment. This assumption has been validated by the Consortium. Complementarily, we have searched for carbon capture key-related products, assuming that, if exported, they are produced and thus, the technology can be deployed by local companies. Specifically, for this purpose we have extracted data from Comtrade (UN, 2021) and the harmonized system standard classification for the products ("commodities") below, confirming that the three regions do export them:

- Commodity code 2921: Amine-function compounds
- Commodity code 840490: Boilers parts of auxiliary plant, for use with boilers of heading no. 8402 and 8403 and parts of condensers for steam or other vapour power units
- Commodity code 841480: Pumps and compressors for air, vacuum or gas, n.e.c. in heading no. 8414
- Commodity code 841950: Heat exchange units not used for domestic purposes
- Commodity code 847960: Machinery and mechanical appliances evaporative air coolers

Once that both sector and country allocations have been designed, the investment vector is ready to be used in the MRIO model as explained in Section 2.1. The logic of this process is replicated both for selected regions and CCS stages.

2.3.2 Transportation

Once captured, power for compressing CO_2 is required. The additional energy is supplied instead of being internalized by adding an energy block. Hence, energy from the country/national grid is considered. These costs are included in the transportation stage, where the conditioning of CO_2 is required, with the exception of the Rhône Valley, where CO_2 is transported in gaseous form via existing pipelines and no liquefaction or compression costs are required. Power for compression is allocated to the *Production of electricity by gas* EXIOBASE sector, accounting for approximately 60% of Transportation VAROM, assuming the same shares as the capture stage. Apart from power for compression, the transport of CO_2 to the storage sites depends on the selected region configuration considered in WP5. Table 2-4 summarizes all the options for transportation. For the **Ebro Basin**, the alternative scenario chosen considers two means of transport: ship (owned) and new pipelines. Ship investments include the purchase of the boats, instead of being rented as outsourced services. This fact explains why ship investments are larger than for new pipelines deployment. Although in the baseline scenario trucks are considered as another mean of transport, under the alternative scenario these are not contemplated. For the **Lusitanian Basin,** new pipelines and train are used; the latter for the pilot units installed in the initial years. Finally, transportation of CO_2 in the **Rhône Valley** considers existing pipelines (whose services are here assumed to be outsourced), ship and train. A special focus is set on the ship cost breakdown: the ship cost breakdown is obtained based on data from (Colling and Hekkenberg, 2020). Since we just want to know about the shares of different components and services on an aggregate basis, this simplification is suited for the present analysis. Manufacture of other transport equipment (35) includes the manufacture of transport equipment such as ship and boat manufacturing, the manufacture of railroad rolling stock and locomotives, air

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and spacecraft and the manufacture of parts thereof. The crew members are long-term staff hired during the period in which the activity takes place. Hence, we consider this as in-plant employment. Fuel costs for the ship are assigned to the petroleum refining industry in EXIOBASE, which includes many refined products converted from crude oil, such as liquefied petroleum gas, gasoline, kerosene, aviation fuel, diesel fuel, and fuel oils.

Table 2-4 Transportation costs breakdown

Mean of transport	Cost breakdown	Participation	Sector allocation (EXIOBASE)
Ship	**CAPEX**		
	Ship	100%	Manufacture of other transport equipment (35)
	OPEX		
	Crew	35%	In-plant effects
	Fuel costs	54%	Petroleum Refinery
	Maintenance	8%	Manufacture of other transport equipment (35)
	Insurance	4%	Insurance and pension funding, except compulsory social security (66)
New pipelines	**CAPEX**		
	Materials	18.8%	Manufacture of fabricated metal products, except machinery and equipment (28)
	Labour	55.0%	In-plant effects
	Miscellaneous (engineering)	19.1%	Other business activities (74)
	Right of way	5.3%	Real estate activities (70)
	CO_2 surge tank	1.8%	Manufacture of machinery and equipment n.e.c. (29)
	Pipeline control system	0.2%	Manufacture of electrical machinery and apparatus n.e.c. (31)
	OPEX		
	O&M costs	78.5%	Manufacture of fabricated metal products, except machinery and equipment (28)
	Electricity costs	21.5%	Transport via pipelines
	CAPEX		
	Materials	18.8%	Manufacture of fabricated metal products, except machinery and equipment (28)
	Labour	55.0%	In-plant effects
	Miscellaneous (engineering)	19.1%	Other business activities (74)
	Right of way	5.3%	Real estate activities (70)
Existing pipelines	**Externalized**	100%	Transport via pipelines
Train	**Externalized**	100%	Transport via railways

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2.3.3 Storage Stage

For the Ebro Basin, WP5 already identifies the Maestrazgo region as the most promising location in both baseline and alternative scenarios. In the Lusitanian Basin, choosing the alternative scenario implies not considering onshore storage, due to social acceptance restrictions, which is done alternatively offshore. CO_2 storage in Southeast of France remains a challenge since some suitable onshore sites in the Rhône Valley are located in protected areas. Although there is a possibility to export CO_2 so as to store it outside France (offshore), there is still room for potential onshore storage locations in France. This latter option is selected in this document (see Table 2-5).

Table 2-5 Storage costs breakdown

Location	Cost breakdown	Participation	Sector allocation (EXIOBASE)
Onshore	Pre FID (final investment decision)	7%	Research and development (73)
	Injection wells	40%	Manufacture of machinery and equipment n.e.c. (29)
	O&M	14%	In-plant effects
	Facilities	26%	Construction
	Measuring, monitoring and verification (MMV)	13%	Research and development (73)
Offshore	Pre FID (final investment decision)	8%	Research and development (73)
	Injection wells	23%	Manufacture of machinery and equipment n.e.c. (29)
	O&M	20%	In-plant effects
	Facilities	44%	Construction
	Measuring, monitoring and verification (MMV)	5%	Research and development (73)

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3 Ebro Basin

The Ebro Basin is a geographical area located in the Northeast of Spain, covering part of three main regions: Cataluña, Aragón and Comunidad Valenciana. Unemployment ranges from 10.7 to 16.7% in the Ebro Basin, depending on the region. The Ebro basin inventory comprises twenty-six industrial facilities emitting more than 0.1 Mt CO_2/y, and totalizing emissions of 17.74 Mt CO_2/y in 2017. Power plants, cement and chemical factories are the dominating sectors, both regarding the number of facilities and the related emissions, accounting for 79% (Coussy, 2021). The **Alternative Industry Scenario** is the scenario that we analyse since it is the most reasonable scenario available for that region. The CCS system considered in this scenario is expected to require 90€/t CO_2 avoided. The scenario contemplates six industrial installations in which capture activities are carried out. These facilities emit, to date, 6.58 Mt CO_2 per year. Only those industrial companies that have CCS in their strategies are considered: Repsol (chemistry and refined petroleum products, that already has CCS technologies as part of the company's environmental strategy) and the cement industry (several companies), where it is understood that CCS in a needed solution for its CO_2-from-process emissions (Coussy, 2021). Altogether, they account for 52% of total emissions in the Ebro Basin. The capture technology is expected to start operating at the end of 30' or early 40', mainly pushed by the two key sectors in the area. Transportation is carried out by on-land pipeline in all cases. Transport by ship is used to transport a large share of the CO_2 mobilized in the scenario to the surroundings of the Alcanar port, for its pipeline shipment to subsequent storage sites. Here we assume that the ship is not owned but an outsourced service: this fact may be overestimating the results, as pointed out afterward. A single onshore storage place (Maestrazgo, Aragón region) is used, optimizing the investment. The network is oversized to incorporate potential new issuers and new needs, which affects the economic costs (and therefore the generation of employment).

The proposed scenario would have a **cumulative investment of approximately 3850 M.EUR** (in 2011 prices) up to the year 2050, in order to install and operate CCS technologies (both in-plant and GVC impacts considered), **boosting the global production to 6880 M.EUR**, with a multiplier effect on the output representing 1.79 times the initial investment. Capture is the most important stage, accounting for 60% of the overall deployment (almost 2330 M.EUR), followed by transportation (35%) and storage (5%). In value added terms, the in-plant labour payments (compensation of employees), mainly at the O&M stage, range from 14.0 to 22.5% of the total figures. The remaining 77.5 – 86% is related to the components and services (direct and indirect) required to deploy the technology, coming from inside and outside Spain (see Figure 3-1). All along this global value chains process, 74.2 to 90.3% of the initial investment is estimated to have its origin in Europe, depending on the stage (see Figure 3-3). On average, **83% of the value generated in the intermediates that Spain needs would come from inside the European Union**. The main sectors in terms of value added come from Spain and are those related to EPC Services (design and engineering costs included in Research and Development), equipment (stripper, absorber, cooler, compressor, included in the Manufacture of machinery and equipment activity), the building and structures, and improvements to the site (Construction sector), all at the capture stage. From the rest of the world, intermediate activities that generate most value include *Extraction of crude petroleum and similar* (for transportation and capture), *Mining and extraction activities* (for capture*), Extraction of natural gas and services related to natural gas extraction* (power for CO_2 compression), and *Supporting and*

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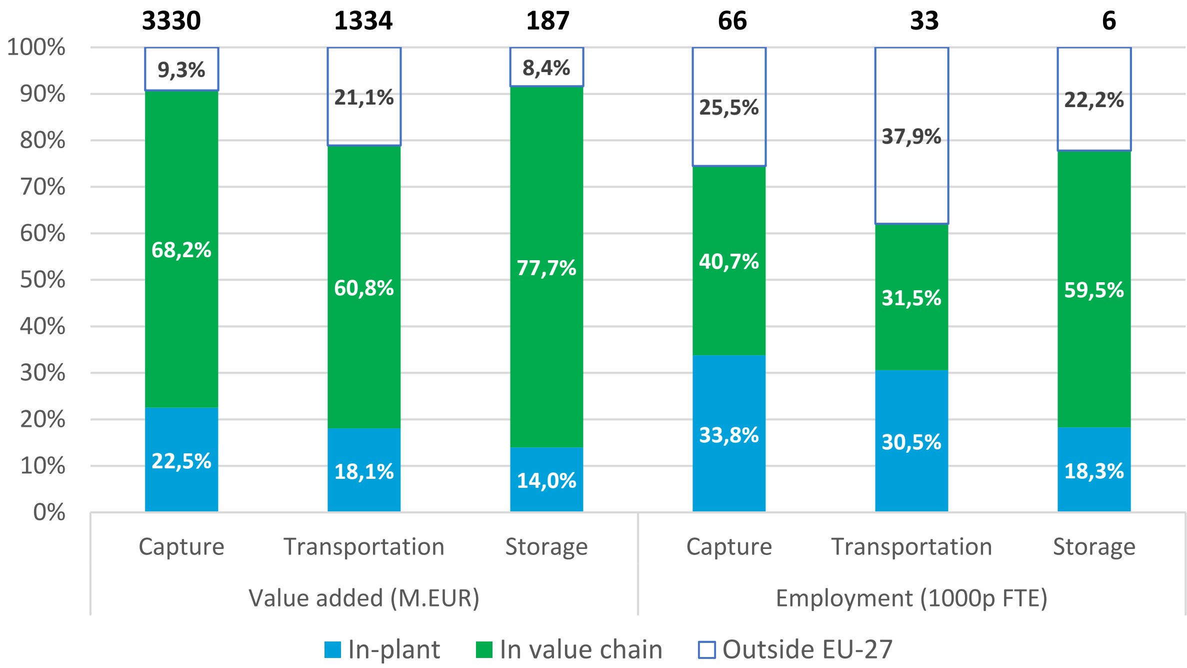
auxiliary transport activities (for transportation). The European Union supports Spain by providing intermediates related to *Trade, Business services and Transport activities* mostly at the capture stage. Figure 3-1 below summarizes the breakdown of socioeconomic impacts related to the CCS deployment in the Ebro Basin under the Alternative Scenario.

Figure 3-1 Socioeconomic impacts of CCS deployment in the Ebro Basin



Employment creation can be understood as net employment since jobs created neither displace nor destroy any current job. According to our results, **approximately 104,900 jobs would be created under the Alternative Industrial Scenario in the 25 years of investment** up to 2050, which means around 4,200 FTE jobs annually (understood as long-term employment), retaining **2,850 in Spain**. All direct employment (In-plant and direct effects) is related to the host country, since we assume there are no direct foreign requirements. Around 51% of total employment creation is direct (33,400 and 20,175 jobs, see Figure 3-2). The rest is related to the intermediates all along the GVC in Spain and outside: 32% of the total jobs created are outside Spain. **Each M.EUR invested in CCS technologies is likely to generate around 18.5 FTE jobs inside Spain**.

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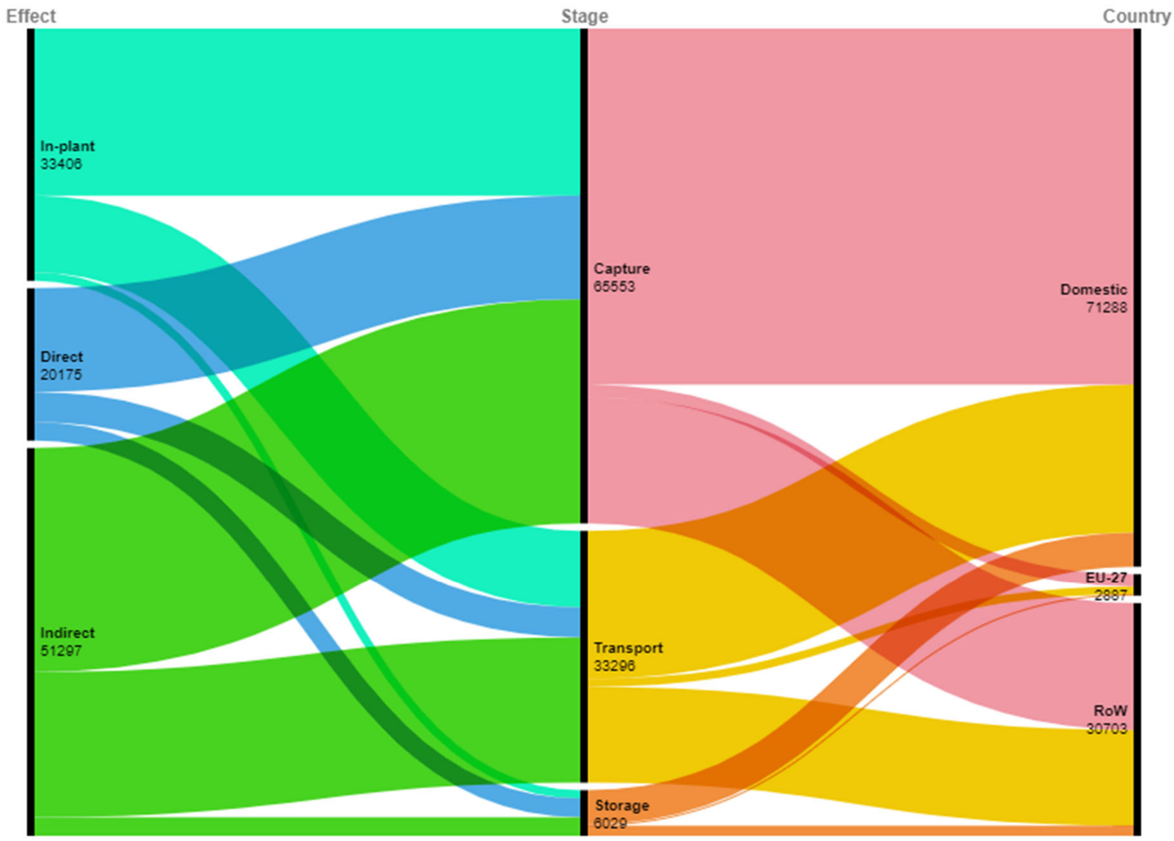
Figure 3-2 Employment creation under Alternative Scenario at Ebro Basin



In-plant employment located in the host country (related to long-term jobs) accounts for 32% of the overall job creation (ranging from 18 to 34% approximately, depending on the stage). The remaining employment creation (66 to 82%) is related to the construction, installation, and intermediate goods and services required for deploying the technology. Zooming into these figures, on average, 68% of the employment in this global value chains phenomenon is originated in Spain, and 3% in the European Union, meaning that the remaining 29% is being created when supplying intermediates outside the EU-27. **Capture is the most job-intensive stage, accounting for 63% of the overall employment creation, followed by transportation (32%).**

Employment in Spain comes from *Research and development, Manufacture of machinery and Equipment, wholesale trade, Chemicals, Construction,* and *Manufacture of fabricated metal products* at the capture stage. Some activities arise with the requirement of intermediates while others are rather related to the initial investments. Altogether, these activities account for 19,000 FTE jobs. The rest of the world creates employment in the *Mining sector* (mainly at the capture stage), as well as *Supporting and auxiliary transport activities* (at transportation stage), and *Other land transport* (capture). These three main sectors are estimated to create 6,400 FTE jobs abroad. The European Union has a more modest role here: the main sectors responsible for employment creation are related to *Trade, business services and other land transport*, accounting for 770 FTE jobs.

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An imbalance is expected between the distribution of employment, industry development and employment associated with storage. The storage stage is related to the Maestrazgo region, while capture and transportation stages remain mostly in Tarragona and Barcelona. The former is sparsely populated while the latter are very densely populated. Since the storage stage is the one that generates less employment, in the storage areas, which are the poorest and most depopulated, employment will hardly increase.

Looking at the indicators in global value chains it can be seen that **the deployment of CCS technologies in Spain relies more on foreign employment than on foreign value added** (see Figure 3-3). For instance, at capture stage, almost 82% of value added would be sourced in Spain (in-plant values excluded), considering that the host country is capable of supplying the goods and services required. The remaining 6.2% and 12% of the initial investment are estimated to originate from Europe and the rest of the world, respectively. That is, 18.2% of the value generated from the intermediates that Spain needs comes from outside the country. Figures regarding foreign employment are higher, especially at the transport stage (see Figure 3-3), where jobs created outside Europe are higher (in-plant employment excluded). Employment creation outside Spain is higher at the capture stage, due to the economic importance of this stage (see Figure 3-3). However, in relative terms, the transportation stage is the most dependent on foreign jobs. High foreign employment at the capture stage is explained by extractive activities (energy and metallic mining like coal, copper, aluminum), transport services and wholesale trade. High foreign employment at the transportation stage is explained by extractive activities like crude oil, natural gas, and manufacture of metallic products, among others.

Figure 3-3 Impacts in Global Value Chains

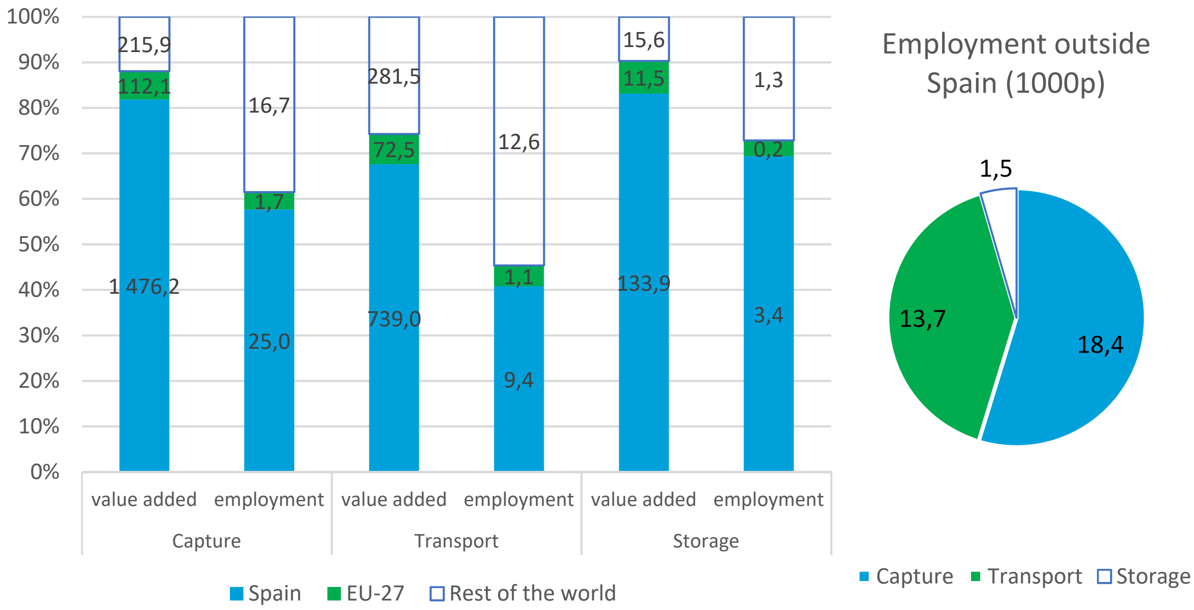

Table 3-1 summarizes data explained in this chapter. Global value chains may have changed from 2011 (latest year available in EXIOBASE), impacting also in the origin and destination of the socioeconomic indicators provided here. However, assuming that changes have not been severe

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during this decade (except during the Covid crisis), these results are an acceptable guidance to understand the underlying effects of economic growth and employment creation when deploying CCS technologies in the Ebro basin.

Table 3-1 Results of the calculated indicators for the Ebro Basin alternative scenario

		Capture		Transportation		Storage		Total	
		Value added	Jobs	Value added	Jobs	Value added	Jobs	Value added	Jobs
	Region	M.EUR	1000p	M.EUR	1000p	M.EUR	1000p	M.EUR	1000p
In the value chain	ESP	1476.2	25.0	739.0	9.4	133.9	3.4	2349.0	37.9
	EUR	112.1	1.7	72.5	1.1	11.5	0.2	196.2	2.9
	ROW	215.9	16.7	281.5	12.6	15.6	1.3	513.0	30.7
		1804.2	43.4	1093.0	23.1	161.0	4.9	3058.3	71.5
In plant	ESP	524.3	22.1	241.0	10.2	26.1	1.1	448.6	33.4
TOTAL		**2328.5**	**65.6**	**1334.0**	**33.3**	**187.1**	**6.0**	**3849.7**	**104.9**
FTE/M.EUR		Total	European	Total	European	Total	European	Total	European
		28.2	21.0	25.0	15.5	32.2	25.1	27.2	19.3

FTE per million euro invested in CCS is aligned with results from other cases. For example, employment in the sector of renewables is estimated around 45 FTE/M.EUR in Mexico (Banacloche et al 2020). For the same country, carbon capture technology creates almost 50 FTE/M.EUR domestically, and 54 to 57 in total (Banacloche et al., 2022). Since the methodology used is the same, higher values correspond to higher employment intensities in the countries and sectors involved.

Another work by SINTEF accounts for 33 FTE/M.EUR domestically speaking (in Norway) and 88 in total: higher figures, but in the same order of magnitude (Størset, et al., 2018). Wind, solar and biomass create 10 FTE/M.EUR according to (Garrett-Peltier, 2010). In the UK, 18 FTE/M.EUR could be created considering a 25-years lifetime of the investments of CCS (Turner et al., 2020). These examples, although depart from the IO approach, use other databases and/or complementary methodology.

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4 Lusitanian Basin

Since Portugal is committed to the carbon neutrality target within 2050, changes are expected to occur in the region towards a reduction of CO_2 emissions. Considering the uncertainties on long-term CO_2 emissions of the Lusitanian Basin, CCUS scenarios have been developed under WP5 considering industry mitigation plans. For the Lusitanian Basin, the Alternative Scenario has been chosen where no onshore storage is contemplated, based on social acceptance. In the Alternative Scenario, CO_2 is stored offshore, transported through pipelines. The main decarbonization strategies are linked to the overall national Cement and the Navigator paper and pulp industries, which aim to become carbon neutral in 2050 and 2035, respectively (ATIC, 2021; Navigator Company, 2019). CO_2 is transported by new pipelines and stored in offshore sites. In the case of the pilots we also consider train as a mean of transport (we assume this service is hired).

With a cumulative investment from 2025 to 2050, **the 4,443 M.EUR invested in CCS technologies in this region (2011 prices) would impact global production 1.78 times, up to 7,900 M.EUR.** Capture remains the most important stage both in terms of value added and employment (3,742 M.EUR and 116,600 jobs), followed by storage (493 M.EUR and 19,000 potential employees). The in-plant labour payments, mainly at the O&M stage, range from approximately 14 to 34.1% of the total figures. The remaining 65.9 – 86% is related to the components and services required to deploy the technology, direct and indirect, coming from inside and outside the European Union (see Figure 4-1). Global value (see Figure 4-3). The main sectors in terms of value added coming from Portugal are related to the capture stage: coal for CHP and natural gas for powering the plant (Production of electricity by coal and gas), EPC Services (design and engineering costs included in Research and Development), equipment (stripper, absorber, cooler, compressor, included in the Manufacture of machinery and equipment activity), building and structures, improvements to the site (Construction sector), and intermediates related to Manufacture of fabricated metal products and electricity production. From the European Union, the intermediates required include Manufactures such as machinery and equipment, and fabricated metal products; also trade and business activities. The rest of the world highlights creating value added from intermediate activities such as *Mining and extraction activities,* and *Extraction of crude petroleum and similar* (at the Capture Stage). At the transportation stage, the most relevant sectors from the rest of the world are transport- and trade-related activities.

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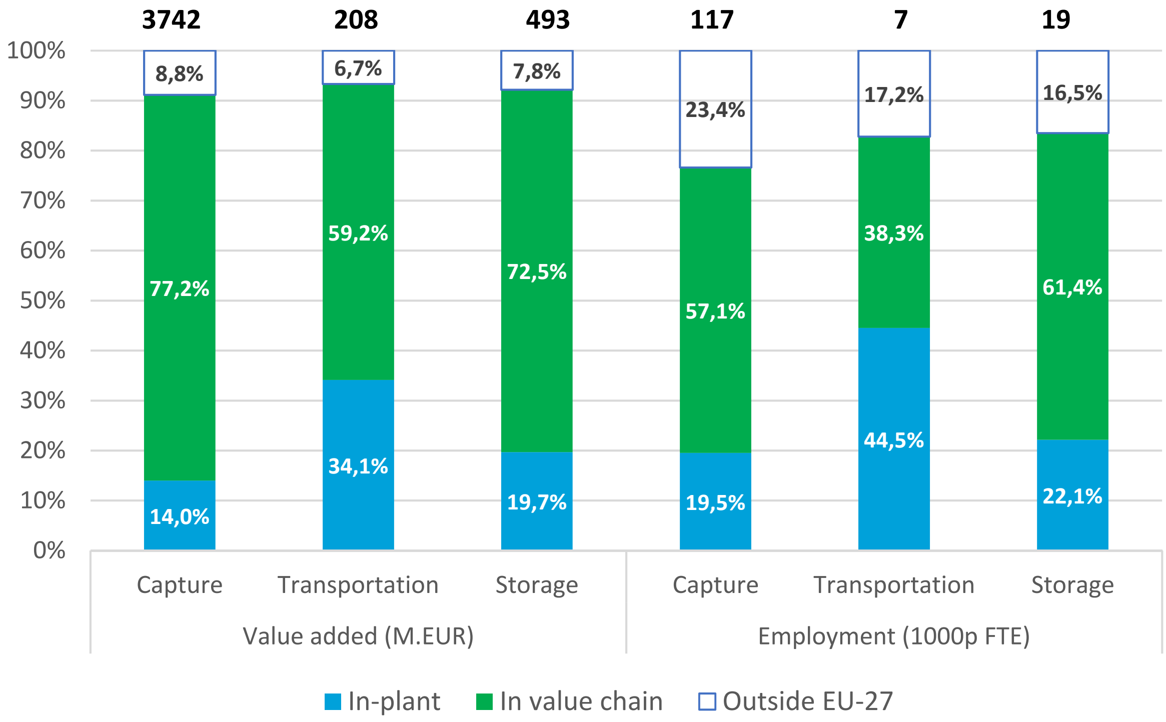
Figure 4-1 Socioeconomic impacts of CCS deployment in the Lusitanian Basin



Employment creation is estimated to around 142,600 FTE jobs during the period 2025-2050, which means around 5,700 estimated FTE per year (see Figure 4-2). Direct employment created in Portugal is expected to account for 52% of the overall job creation (in plant 30,090 FTE plus 43,900 coming from the final components and services required for the deployment of CCS technologies). Indirectly, from GVC, around 68,650 FTE would be created: 30,650 in Portugal, 6,400 in the European Union and almost 31,600 outside. **Employment tends to be more reliant on the outside when compared to value added**, highlighting the capture stage, where 23.4% of the employment comes from outside the European Union, related to indirect impacts in the GVC. However, when compared to the Ebro Basin, Portugal remains less dependent on foreign requirements. A FTE/M.EUR invested in Portugal are higher than in the case of Spain: **on average, each million invested in CCS technologies in Portugal is estimated to create 32.1 FTE jobs** (direct and indirect) **during the period 2025-2050**, where 25 are retained in the European Union (see Table 4-1).

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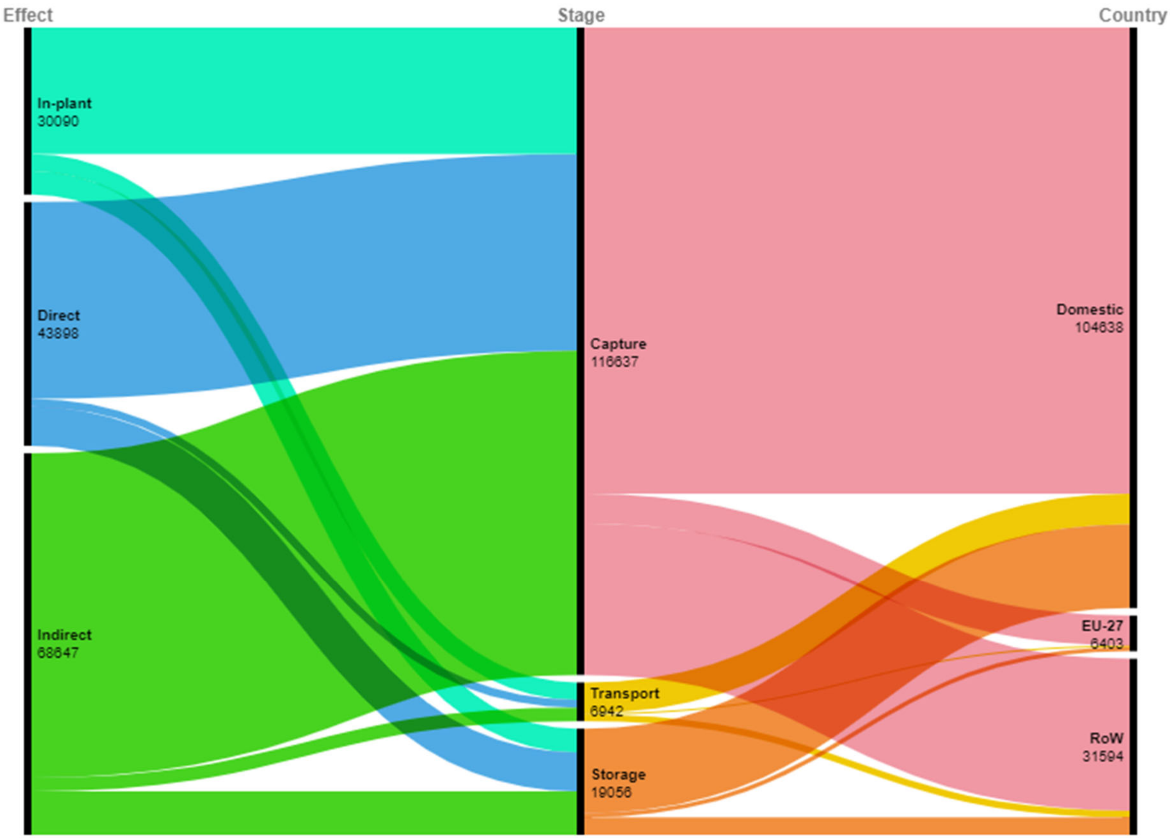
Figure 4-2 Employment creation under Alternative Scenario at Lusitanian Basin



Capture is the most job-intensive stage, accounting for 82% of the overall employment creation, followed by Storage (13%). In-plant employment located in the host country (related to long-term jobs) accounts for 30,090 FTE jobs during the lifespan of the technology, 21% of the overall job creation (ranging from 19.5 to 44.5% approximately, depending on the stage). The remaining employment creation (55.5 to 80.5%) is related to the construction, installation, and intermediate goods and services required for the deployment of the technology. Zooming into these figures, on average, 73% of the employment in this global value chains phenomenon is originated in Portugal, and 4.5% in the European Union, meaning that the remaining 22% is being created when supplying intermediates outside the EU-27.

Employment in Portugal comes from *Manufacture of machinery and Equipment, Research and development, Construction, Production of electricity by coal* and *Manufacture of fabricated metal products* at the capture stage. Some activities arise with the requirement of intermediates while others are rather related to the initial investments. Altogether, these activities account for almost 43,800 FTE jobs. The rest of the world creates employment in the *Mining sector* (mainly at the capture stage), as well as *Trade services*, *Manufacture of machinery*, and *Other land transport* (at the capture stage). These three main sectors are estimated to create 11,000 FTE jobs abroad. The European Union´s main sectors responsible for employment creation are *Manufacture of machinery*

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and equipment n.e.c., Manufacture of fabricated metal products, Trade and business services, accounting for 2,900 FTE jobs.

Once again, regarding the indicators in GVC, two conclusions can be extracted from Figure 4-3: 1) foreign employment is higher than foreign value added; 2) the capture stage is the most dependent on outside the EU-27. Employment creation outside Portugal is higher at the capture stage, due to the economic importance of this stage (see Figure 4-3). Foreign employment at the capture stage is explained by extractive activities (metallic mining), transport services, wholesale trade and manufacture of machinery, among others. Foreign employment at the Transport stage is explained by Trade activities, Transport services and other business activities. Higher dependences (in relative terms) arise at the transportation stage, due to the production of intermediates related to power for compression and the outsourced services of train. The targets for electricity in Portugal are settled in 80% renewables by 2030 and 100% by 2050. This fact has not been included in the assessment. Hence, the situation could change if power for compression relies on other sources than fossil fuels as expected. Finally, Table 4-1 summarizes data explained in this chapter.

Figure 4-3 Impacts in Global Value Chains

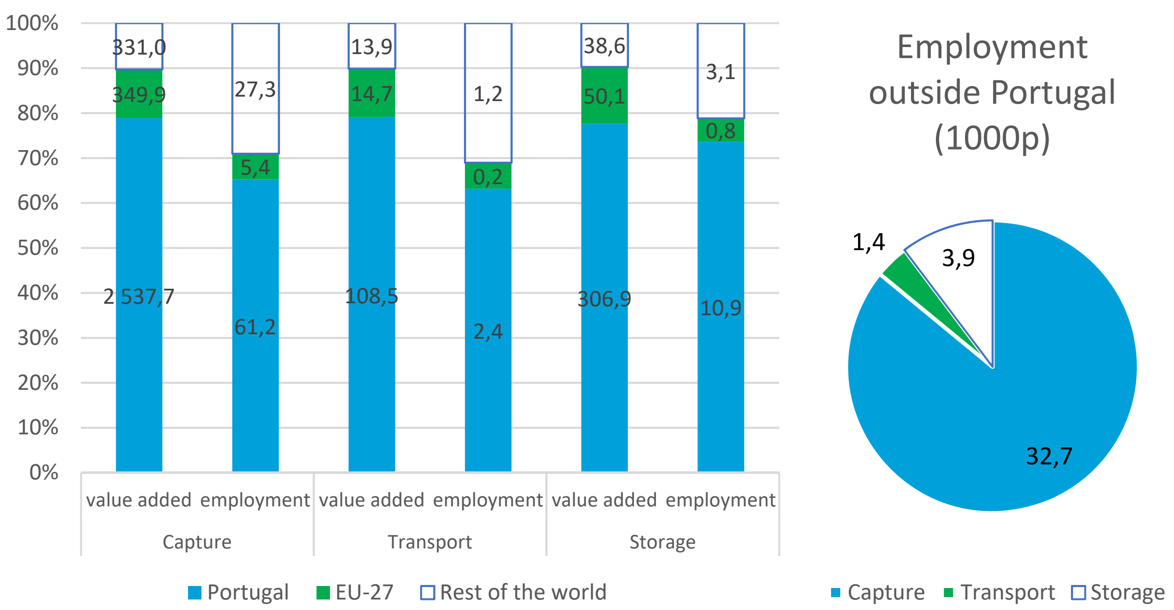

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Table 4-1: Results of the calculated indicators for the Lusitanian Basin scenario

		Capture		Transportation		Storage		Total	
		Value added	Jobs	Value added	Jobs	Value added	Jobs	Value added	Jobs
	Region	M.EUR	1000p	M.EUR	1000p	M.EUR	1000p	M.EUR	1000p
In the value chain	PRT	2537.7	61.2	108.5	2.4	306.9	10.9	2953.2	74.5
	EUR	349.9	5.4	14.7	0.2	50.1	0.8	414.8	6.4
	ROW	331.0	27.3	13.9	1.2	38.6	3.1	383.4	31.6
		3218.6	93.9	137.2	3.9	395.6	14.8	3751.4	112.5
In plant	PRT	523.6	22.8	71.0	3.1	97.0	4.2	448.6	30.1
TOTAL		**3742.2**	**116.6**	**208.2**	**6.9**	**492.6**	**19.1**	**4443.0**	**142.6**
		Total	European	Total	European	Total	European	Total	European
FTE/M.EUR		31.2	23.9	33.3	27.6	38.7	32.3	32.1	25.0

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5 Rhône Valley

The Rhône Valley chosen scenario is the Main scenario, including emitters from industrial activities such as iron and steel, refineries, hydrogen, energy from waste, chemicals, and cement. Regarding transportation, existing gas and oil pipelines are considered to be reused for carrying CO_2 captured in the Rhône Valley to the final onshore storage site in the Paris Basin from 2040 to 2050. No boosting/compression station is needed for the existing oil pipeline (used to transport CO_2 on 360 km out of 700 km separating Fos-sur-Mer where CO_2 is captured, and Donnemarie where CO_2 is stored). Due to the uncertainty and constraints related to storage, ship transport (bought) has been considered for eventual transportation inside France.

Starting the investment in 2023, the 1,180 M.EUR invested in CCS technologies up to 2050 (2011 prices) would almost double global production, i.e. up to 2,122 M.EUR. Capture remains the most important stage both in terms of value added and employment (730 M.EUR and 16,680 jobs). Unlike Spain or Portugal, transportation (199 M.EUR and 6,000 employees) and storage (250 M.EUR and 5,600 jobs) in the Rhône Valley Mase scenario are more alike. The in-plant labour payments (value added), mainly at the O&M stage, range from approximately 14 to 28.1% of the total figures. The remaining 71.9 – 86% is related to the components and services required to deploy the technology, direct and indirect, coming from inside and outside the European Union (see Figure 5-1). Global value chains are likely to have a higher impact in the rest of the world when compared to the European Union (France excluded) (see Figure 5-3). The main sectors in terms of value added coming from France include the manufacture of machinery and equipment (related to the injection wells at the storage stage), transport via pipelines (outsourced services for CO_2 transportation through existing pipelines), construction services related to the building and structures both at the storage and capture stages, among others (including research and development, trade services, and manufactures of metal products). The rest of the world region highlights by contributing with transport services (transport via pipelines, manufactures of other transport equipment related to the ships) and extractive activities (mostly energy-related, like crude petroleum and nuclear fuels); most of them at the transportation stage. For instance, it is not only transport via existing pipelines what implies ROW manpower, but the whole transportation stage (intermediates related to fabricated metal products, transport equipment, etc.) that indirectly, along the successive rounds of production, requires foreign employment, and part of it is created in “transport via pipelines”. The European Union also highlights providing intermediates related to the manufacture of other transport equipment, wholesale trade, transport via pipelines, manufacture of fabricated metal products and other business activities.

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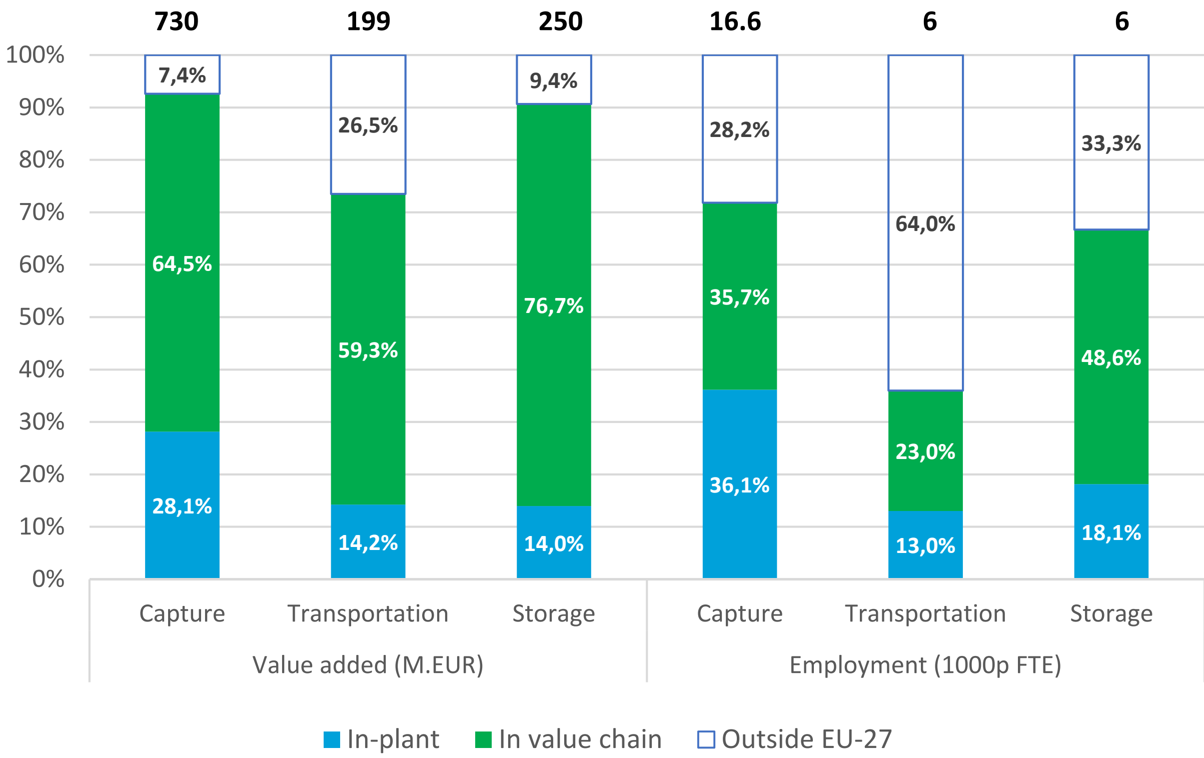
Figure 5-1 Socioeconomic impacts of CCS deployment in the Rhône Valley



Job creation in France is estimated around 28,700 FTE approximately, during the 27 years of investment starting in 2023. This could also be understood as 1,148 FTE permanent jobs in the period 2025-2050. Direct employment created in France is expected to account for 40% of the overall job creation (in-plant 7,840 and around 3,700 coming from the final goods and services required for the deployment of CCS technologies). Indirectly, from GVC, the remaining 60% would be created: 17,000 FTE jobs coming from France (5,300), EU-27 (around 1,100), and the rest of the world (more than 10,600). Employment tends to be more reliant on the outside, highlighting the transportation stage, where 64% of the employment comes from outside the European Union, related to indirect impacts in the GVC.

Transportation being a stage that outsources pipeline services, job creation at this stage is mostly related to in-plant jobs coming from the required ship crew. In terms of FTE/M.EUR, on average, **each million invested in CCS technologies in France is estimated to create 24.3 FTE jobs (direct and indirect) during the period 2023-2050**, where 15.3 are retained in the European Union (see Table 5-1). This is mostly explained by the higher wages of French workers.

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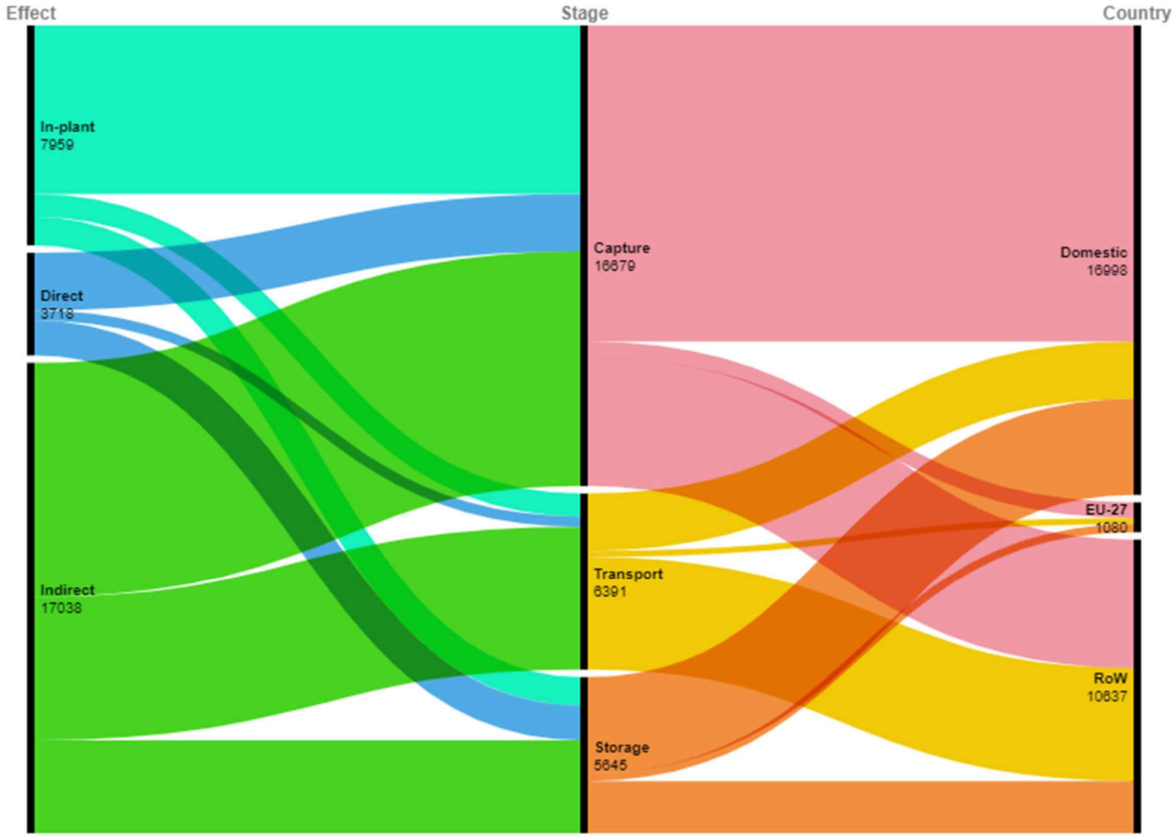
Figure 5-2 Employment creation under the Main scenario in the Rhône Valley



Capture remains the most job-intensive stage, although accounting for 58% of the overall employment creation, followed by transportation (22%) and storage (20%) stages. In-plant employment located in the host country (related to long-term jobs) accounts for 7,959 FTE jobs, 27% of the overall job creation (ranging from 13 to 36.1% approximately, depending on the stage). As seen before, indirect employment here mainly comes from the rest of the world. Hence, we can infer the GVC among France and outside the EU-27 in industries and activities that are likely to represent the CCS technologies presented: the intermediates required to deploy CCS in France are estimated to be provided mostly by non-EU Member States. One of the main virtues of the input-output analysis is the completeness regarding the measurement of indicators such as these provided here. However, one of the main disadvantages is the level of aggregation, meaning that specific processes such as CCS deployment might not be perfectly described by this methodology. Therefore, other approaches such as life cycle analysis performed in WP4 are necessary. Hence, it is not a fact that CCS in France will be provided mostly by non-EU Member States, but an estimation, according to the GVC functioning at an aggregated level.

Employment embodied in GVC in France comes from research and development related activities: pre-FID (final investment decision); measuring, monitoring and verification (MMV) at the storage stage; as well as EPC services (design and engineering costs) at the capture stage. Also, construction

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services, transport via pipelines, and manufacture of machinery. Altogether, these activities create, directly and indirectly, more than 5,600 FTE jobs out of 16,998. Departing from the indicators in the GVC of Figure 5-3, the narrative is the same as for the Ebro and Lusitanian basins: **foreign employment is higher than foreign value added**. The rest of the world creates employment in Transport services (via pipeline and other land transport), the *mining sector* (energy and metallic mining), as well as *trade services*, *manufacture of other transport equipment* (for the ships). These activities are estimated to create almost 2,700 FTE jobs abroad. The employment originated in the European Union comes from trade services, manufacture of fabricated metal products, manufacture of other transport equipment, manufacture of machinery, and business activities; accounting for more than 400 FTE jobs.

Figure 5-3 Impacts in Global Value Chains

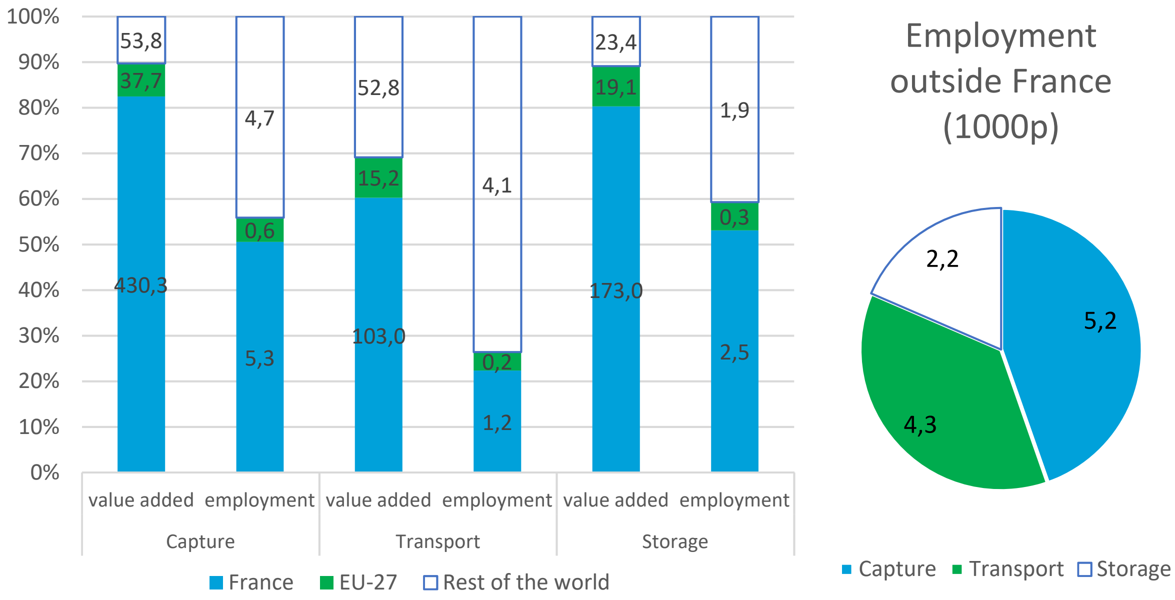

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Table 5-1: Results of the calculated indicators for the Rhône Valley Main scenario

		Capture		Transportation		Storage		Total	
		Value added	Jobs	Value added	Jobs	Value added	Jobs	Value added	Jobs
	Region	M.EUR	1000p	M.EUR	1000p	M.EUR	1000p	M.EUR	1000p
In the value chain	FRA	430.3	5.3	103.0	1.2	173.0	2.5	706.3	9.0
	EUR	37.7	0.6	15.2	0.2	19.1	0.3	72.0	1.1
	ROW	53.8	4.7	52.8	4.1	23.4	1.9	130.0	10.6
		521.8	10.6	171.1	5.6	215.5	4.6	908.4	20.8
In plant	FRA	208.3	6.1	28.4	0.8	34.9	1.0	448.6	8.0
TOTAL		**730.1**	**16.7**	**199.4**	**6.4**	**250.5**	**5.6**	**1,180.0**	**28.7**
FTE/M.EUR		Total	European	Total	European	Total	European	Total	European
		22.8	16.5	32.1	11.5	22.5	15.0	24.3	15.3

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6 Conclusion

Results regarding socioeconomic impacts (value added and employment) of CCS deployment in the chosen scenarios settled by WP5 regarding three selected regions (Ebro Basin, Lusitanian Basin and Rhône Valley) were presented. **In the selected scenarios, more than 9,470 M.EUR could be invested in CCS technologies during the period 2023-2050 (at 2011 prices), contributing to capture almost 190 Mt CO_2 (and storing 70%). Part of the invested amount would be creating value added and employment outside the European Union, due to global value chains (GVC)**. **Inside the EU-27, around 89% of the total investment would be retained in terms of value added, and 74% of the total employment generated, contributing to 8,130 permanent jobs.**

The multiplier effect of these investments is slightly higher in the Rhône valley, although boosting more foreign intermediates than in the case of Ebro and Lusitanian basins. Also, it is proven that GVCs matter, since more than 1 out of 4 jobs are created outside the EU-27 on average. These investments would generate more employment in Portugal: 32.1 FTE/M.EUR invested (25 retained in Europe). In the case of the Ebro Basin, the Storage of CO_2 is the stage that creates most employment per million invested, followed by capture. In the Lusitanian Basin it is also storage, but followed by transportation. On the contrary, in the Rhône Valley transportation creates more employment (32.1 versus 11.5 European FTE/M.EUR). While capture is the most important stage in socioeconomic terms, transportation tends to be the most dependent stage on foreign requirements and productive factors (in relative terms), usually due to fuel and other energy requirements. This fact supports the dependance of France to some intermediates required in CCS investments. On the other hand, Portugal is more integrated and less dependent on the intermediates (and embodied employment) from the rest of the world.

As for the Ebro basin, higher dependences (in relative terms) arise at the transportation stage, due to the production of intermediates related to power for compression and building the ships. This situation could change if power for compression relies on natural gas. On the other hand, petroleum-derived products for the ships (with high imported content) are more difficult to substitute and hence, part of these high dependences are not likely to be reduced. In-plant employment in the Rhône Valley in the transportation stage only comes from the ship crew; if no sea transport is undertaken and only existing pipelines are required, this employment should not be considered.

One of the main assumptions is that every region will be capable of developing a CCS industry and network to provide the final components (goods and services) at every stage. Having to import machinery, construction, or engineering services, would unavoidably reduce the results on domestic employment creation presented here. Another limitation of the analysis is the uncertainty regarding the future of CCUS (not scaled-up technologies yet). Hence, the figures presented have to be understood as potential approximations that might change along with other parameters (different employee compensation, direct imported components and services, changes in the learning factor cost reductions, substantial changes in the economic structure in the GVC, progressive changes in the electricity mix, among others). Despite all limitations presented, the present document is useful to embrace the potential socioeconomic benefits of CCS deployment in Europe, identifying the likeliness of retaining employment and value added inside the regions considered.

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