Central European Journal of Geography and Sustainable Development
ISSN 2668-4322, ISSN-L 2668-4322
2025, Volume 7, Issue 1, Pages: 6-22
https://doi.org/10.51865/CEJGSD.2025.7.1.1

Sustainable practices in the chemical industry: Insights from EU Taxonomy reporting

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Received: 31 December 2024; Revised: 20 January 2025; Accepted: 24 January 2025;
Published online: 27 January 2025

ABSTRACT: This research looks at the corporate sustainable revenues, operational expenses and capital expenses to understand how they are linked to the broader sustainability strategy of corporations. We look at publicly listed companies in the chemical sector, within the context of the EU Taxonomy regulation. The objective of our research is to gather and examine data on economic activities in accordance with the EU Taxonomy regulation. We specifically concentrate on the revenues, capital expenditures (CAPEX), and operating expenditures (OPEX) associated with eligible and aligned operations. We used Python module to create an automated procedure for obtaining EU Taxonomy data from PDF reports of major corporations. Our findings suggest that aligned activities make up just a tiny portion of the total turnover, CAPEX and OPEX in the chemical industry. We then analyze the challenges faced by the chemical industry in transforming their operations to foster sustainability. Our findings not only provide a detailed view on the economic activities of chemical companies but also enhances the comprehension of how reporting disclosure could provide more information for policy makers to support the implementation of sustainable policies.

KEYWORDS: sustainability, chemical industry, EU Taxonomy, ESG, annual reporting

TO CITE THIS ARTICLE: Nita (Danila), A.C. (2025). Sustainable practices in the chemical industry: Insights from EU Taxonomy reporting. *Central European Journal of Geography and Sustainable Development*, *7*(1), 6–22. https://doi.org/10.51865/CEJGSD.2025.7.1.1

1. INTRODUCTION

The chemical industry plays a crucial role in the global markets by producing raw materials that are requested by a wide range of companies operating in different industries and sectors. Despite this, the chemical industry is also a significant contributor to the greenhouse gas emissions generated in the atmosphere. With the increase concerns on climate change impacts and the need to have more stringent climate-oriented regulations such as COP27 and the EU taxonomy, the chemical industries need to undergo significant transformation to adjust their operations towards more sustainable practices. This needs to be seen on the wider perspectives as chemical companies will have to make some tradeoffs between protecting the environment and responding to changing market demands. Chemical companies need to lower their environmental footprint while simultaneously increasing profitability and preserving a competitive edge in the market by focusing on innovative and sustainable products and technologies. In this area, we mention notable developments in circular economy (Wiprächtiger & Hellweg, 2024), technical advancements, calculating the product carbon footprint for their chemical products (Solvay, 2023) or blockchain tracking of raw materials (Bacchetta et al., 2021).

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In light of the new EU Taxonomy regulation, companies face a new compliance regulation in order to asses if their economic activities are sustainable. The regulation, part of the EU efforts to fulfill the European Green Deal has as objective the creation of a shared common classification for sustainable activities. Moreover, it cans also be used as a tool for companies and investors to make sustainable decisions. Using key performance indicators like turnover, capital expenditures (CapEx), and operational expenditures (OpEx), chemical businesses are required to reveal their efforts to promote sustainability in accordance with the regulation. Companies are able to demonstrate their alignment with sustainability goals and promote transparency to stakeholders if they adhere to these reporting requirements and make them a part of their operations. At the core of the regulation, a sustainable economic activity needs to contribute to at least one of the six environmental objectives and do no significant harm to the other states objectives. Among the Taxonomy objectives we remind of climate change mitigation, climate change adaptation, protection of water and marine sources, circular economy, prevention and management of pollution and restauration of biodiversity.

The aim of this article is to assess the level of green revenues and investments of companies operating in the chemical sector and how they fit in the long-term strategy linked to sustainability. We look at multinationals active in the chemical sector, within the context of the EU Taxonomy legislation. We specifically concentrate on revenues, CAPEX and OPEX associated with eligible and aligned operations. To this extent, we employ data science technologies like Python to create an automated procedure for obtaining EU Taxonomy data from PDF annual reports. With this research we intend to close the gap and provide more insightful information on the activities the chemical companies decide the invest and their level of sustainability. We delve into the literature on corporate investments and ESG reporting to understand the major trends in the chemical industry. We then proceed to the description if the tools used in the data collection and processing. Results explore the different KPIs on which the companies report, their eligibility and alignment to the EU Taxonomy criteria. We present detailed information related to the objectives tackled and the activity sector to which the activities are linked to. We then look at the drivers and causes that are linked to the development of sustainable practices in the chemical industry.

2. LITERATURE REVIEW

The literature review has the objective to provide insights into the efforts of chemical companies to integrate sustainability in their long-term strategy of development. Recent studies reveal that the chemical companies face a complex landscape in their attempt to remain competitive but also in producing more eco-friendly products and reduce in the same time the hazardous waste generated by the chemical products (Song & Han, 2014). The term of “green chemistry” is becoming more and more relevant as there is an increasing concern for the chemical companies to operate more sustainable and to create green products by eliminating their footprint on the environment (Kidwai, 2006). Furthermore, as chemical companies are part of a wider and complex supply chain, their environmental footprint has repercussions on the entire value chain (Rajeev et al., 2019). By the same token, circular economy has gained traction as it can be an important driver in manufacturing more sustainable products and reduce waste by revalorizing waste as raw material (Mohan & Katakojwala, 2020). However, to incorporate circular economy in the daily operations of a chemical company requires a set of clear guiding principles and changes in the operational process.

Another important aspect to take into consideration is the increase in regulatory pressures and their impact on the economic activities of chemical companies. A study by Mady et al. (2024) showed that regulatory compliance on sustainability and the market pressures foster eco-innovation on the analyzed companies, becoming thus, more competitive. This is in line with other studies (Amara & Chen, 2022; Jun et al., 2019) that concluded environmental regulation as one of the main drivers for eco-innovation among manufacturing companies. As the European ESG compliance system becomes more transparent, European companies are faced with other regulatory burden along with the ones already existent. The Global Reporting Initiative (GRI) standards or the Sustainability Accounting Standards Board (SASB) were already exerting pressure on companies to disclose their data on sustainable practices. With the enforcement of the Corporate Sustainability Reporting Directive (CSRD) and the EU Taxonomy, the European companies are faced with additional disclosure requirements raising concerns on the cost of compliance and their effect on the overall development strategy of the companies. Materiality assessment

has become a requirement as part of the CSRD disclosure that European chemical companies need to undergo every year. A study conducted on chemical companies' disclosure in 2021 and 2021 found that the industry is having impacts on energy consumption, pollution prevention, health and safety in the workplace and waste and water management (Papafloratos et al., 2023). Among other aspects that were found to be of interest for the chemical industry are human rights issues, reducing GHG emissions and community investment (Liew et al., 2014). Materiality assessment and disclosure it is not sufficient if it lacks clear and transparent methods stated in the annual reports of multinationals. A study done on more than 100 annual reports published by 30 companies listed on the German Stock Exchange found that companies do not reveal the steps taken into the materiality assessment (Beske et al., 2019).

With the new EU Taxonomy regulation as part of the CSRD disclosure, companies need to canalize more resources to make sure they comply with the requirements. This means that they need to asses their economic activities according to the eligibility and alignment criteria stated in the regulation. A study conducted in 2023 by PWC found that 46 % of the companies surveyed needed to employ additional resources to comply with the regulation while more than 60% of the companies stated that they rely on external service providers for this task (PWC, 2022). The same study was carried out in 2023 and 2024 to assess the evolution of the EU Taxonomy reporting. The findings suggest that companies from all industries need to incur higher costs directly linked to the disclosure, do not have a standardized process in collecting the data needed while the most common tool used in excel. In 2023, more than 90% of the analyzed companies report their EU Taxonomy data. The majority use the template provided by the European Commission. With respect to the eligibility and alignment criteria the study found that the shares of economic activities increased in both groups suggesting the European companies are willing to invest in sustainable activities from where they can also generate green revenues (PWC, 2024). Although there are more than 500 companies included in the study conducted in 2024, there is no detailed information on the breakdown of activities by type, sector or industry. Moreover, there is no focus on industries or the specific activities from which the generate revenues or undertake green investments.

3. RESEARCH METHODS

Our research focuses on the data reported by nonfinancial companies in line with the EU Taxonomy regulation. As already specified previously, the regulation aims at providing a clear, transparent and comparable classification of sustainable economic activities. Under the EU Taxonomy, companies that are already subject to the NFRD (Non-Financial Reporting Directive) would need to report data on Turnover, CAPEX and OPEX that are eligible and aligned to the technical screening criteria set out in the regulation. In addition to the NFRD regulation, companies subject to the EU taxonomy are also those that fall under the CSRD (Corporate Sustainability Reporting Directive) regulation. These KPIs show to the investors but also to the wider public the level of commitment of the reporting company towards sustainability. Turnover refers to the revenues generated from the sales of products or services created by the company. CAPEX or Capital Expenditures refer to tangible and intangible assets that a company is willing to make investments in to further support its operating business. OPEX refer to operational expenditures and include expenses linked to the daily business operation of a company like research and development or maintenance. For the purpose of this research, we collected data on these three KPIs from companies that fulfilled at least two out of the three criteria set up in the CSRD regulation. In particular, targeted countries that need to have for the financial year 2023 1) more than 250 employees, 2) a balance sheet of more than 25 mil EUR and 3) turnover more than 50 million EUR. The main focus of this research is to understand what is the level of sustainability of the chemical companies and in what economic activities they decide to investment as part of their long-term strategy. To be able to answer these questions we need to:

- collect the data reported by chemical companies under the EU taxonomy;
- process the collected data to structure it for further analysis;
- assess what is the level of revenues and green investments for the analyzed chemical companies according to the EU Taxonomy guiding principles;
- draw insights on how the chemical industry is adapting to the European ESG compliance framework and what is the impact on the value chain, stakeholders and society.

3.1. Data collection

To be able to collect reported data we would need first to identify the companies targeted by the EU Taxonomy. We use Euronext to find public listed entities with more than 250 employees and that have at least 50 mil EUR in turnover or balance sheet of 25 million EUR for the year 2023. Euronext provides an exhaustive list of companies that are publicly listed belonging to different industries like technology, the financial sector, the healthcare industry, the energy sector, and many more. It offers information related to the company's profile in terms of the economic activities that it operates, the country where the headquarters of the company are located, its financial performance, and other key metrics like revenues, employees, and market capitalizations. Then, we consult the website of targeted companies to extract the EU taxonomy data published in their annual report. Some companies prefer to publish these data in their annual report under the non-financial report while other companies prefer to publish EU taxonomy data in the sustainability report.

We have identified 770 companies that are subject to the EU taxonomy. Out of these, only 26 companies are operating in the chemical sector. For the purpose of the industry classification, we used Euronext level II. We take this as a base for our data collection process. Out of the 26 companies identified, only 19 reported their EU taxonomy data. For the 7 companies remaining either we could not identify the report where the data was published either the reporting was not made using the templates provided by the European Commission. We use Python programming language, to be able to automate the process of data collection from PDF files and save the information that was extracted in an organized Excel format. The methodology employs Python and Jupiter Notebooks as software to write the code necessary for data extraction and collection. Python is an adaptable, high-level, interpreted programming language that has risen to prominence in computer science and academia. Python is fairly easy to use it an excellent choice for both novice and experienced programmers. Alongside Phyton we employ Jupyter Notebook, an open-source platform that is built upon the Python project. It facilitates interactive and exploratory analysis, visualization, and documentation of data. It provides a single environment where code, text, and visualizations may be easily integrated.

Within Phyton we use two types of libraries: pandas and tabula. Pandas is a Python library that is widely recognized for its significant impact in the field of data manipulation, analysis, and organization. It provides a comprehensive technical toolkit for efficiently managing both structured and unstructured data. It has the ability to read and write data from different file formats including PDF, CSV, Excel, SQL databases, and JSON. It employs algorithms that can recognize table borders, rows, and columns included inside PDF files. It has the ability to accurately distinguish table cells, text, and numerical values, making it easy as process of data extraction from a variety of tabular forms. On the other side, pandas library is crucial in the code as it helps with organizing, manipulating, and analyzing the extracted data from PDF files. This library ensures that the data is presented in a structured format that allows us to easily extract insights from the data. It is worth mentioning that the output file generated by the Phyton code contained some unstructured data that makes it difficult to make further analysis. Some manual manipulations of the data were required to be able to get some insights from the reported data.

3.2. Data processing

Data processing is the essential first step in transforming unprocessed data into usable insights. Following the data collection step, it is important to organize, clean, and analyze the data in order to guarantee that it fulfills the objective of collecting EU taxonomy data derived from annual reports of significant corporations. It is worth mentioning that the libraries used in conjunction with Phyton were able to read data from PDF tables and transpose them into excel files. However, since the taxonomy reporting is still new, some companies choose to report their data in a different table structure than the template provided by the EU Commissions. When putting all this data together in one single file, there is a risk that data is not perfectly aligned in rows and columns under the same data field or attributes that could be further used for descriptive statistics and analysis. Therefore, for the purpose of this report, data needed some manual manipulation to make sure that it could be used for further analysis. This meant, rows and columns rearrangement, transformation from units to millions or adding additional columns in order to be consistent across the dataset. Furthermore, in some instances, the values for the listed economic activities were missing.

To ensure that we capture the correct reporting of companies we also keep those activities even if there is no associated value. Given that the source is mostly composed of PDF files, there is the potential for mistakes to occur throughout the extraction process. To counteract any possible errors linked to the data extraction we have compared the data extracted with the source data in the pdf files. Some of the reported data needed rectification following this check. For the majority of data points collected, we kept the abbreviations employed provided in the EU Taxonomy reporting template: Eligible Activities (A), Aligned Activities (A1), Non-Aligned Activities (A2), Non-eligible Activities (B) and Total Activities (A+B). In addition, processing data on individual activities was more difficult as there is always an associated code and name of the reported activity. To keep things simple, we have only kept the codes and then we map them with the codes found in the Taxonomy regulation along with the targeted objective. Data was collected and processed during July and August 2024 and it refers to the latest available information on the companies selected up until this point in time.

4. RESULTS

The scope of this research includes 19 chemical companies[1] that have reported KPIs in the context of the EU Taxonomy regulation. It is important to note that more than 70% of the targeted companies have reported their data. This is in line with a PWC (2024) findings that analyses the EU Taxonomy disclosures. Table 1 and Table 2 offers a detailed analysis into the breakdown of economic activities that are associated with taxonomy-aligned and non-aligned operations. These metrics include turnover, CAPEX, and OPEX for the 19 companies included in our dataset. We look at the mean of reported activities in terms of percentage from the total of activities and their standard deviations. Table 2 depicts the total activities reported by the companies in the data sample for each category of activity, its mean and standard deviation. It is important to mention that companies need to disclose the total of aligned, not aligned, eligible and not eligible activities as part of their reporting. Additionally, companies need to disclose the detailed breakdown of aligned vs not-aligned activities according to the EU Taxonomy compass by associating each activity to a sector and objective. From table 1 we see that the standard deviation is low for Non-Eligible B activities for all KPIs reported suggesting that there is low variability in the dataset. Most activities linked to turnover, CAPEX and OPEX reported by the chemical companies are not subject to the EU Taxonomy screening.

Table 1. Breakdown of economic activities according to the EU Taxonomy classification by Turnover, CAPEX and OPEX (mean and standard deviations for activities expressed as percentage of total activities reported).

Taxonomy Activities	No. of obs	Turnover		CAPEX		OPEX	
		Average %	Std. Dev	Average %	Std. Dev	Average %	Std. Dev
Total Aligned A1	19	3.89%	9.87%	7.59%	16.59%	5.91%	13.52%
Total Non-Aligned A2	19	9.15%	12.58%	17.16%	19.86%	14.78%	16.75%
Total Eligible A1+A2	19	12.85%	15.48%	24.73%	23.35%	18.27%	17.29%
Non-Eligible B	19	87.14%	15.48%	71.03%	27.38%	81.73%	17.29%
TOTAL A+B	19	100.00%	0.00%	100.00%	0.00%	100.00%	0.00%

Source: Author's own calculation with R software based on data collected from annual reports of chemical companies.

In terms of eligibility, we observe that only a small percentage of activities are subject to the EU Taxonomy with CAPEX having the largest share, almost 25%, while turnover has the largest amount among the three KPIs reported with almost 26 billion EUR in total. Turnover also has the largest share of non-eligible activities with 87% of economic activities not suitable to be subject to the technical screening criteria.

[1] The chemical companies included in the data sample are: AIR LIQUIDE, AKZO NOBEL, AQUAFIL, AZELIS GROUP, BASF, BORREGAARD, BRENNTAG, COVESTRO, ELKEM, IMCD, K+S, LANXESS, OCI, ROBERTET, SAES GETTERS, SOL,, SOLVAY, TESSENDERLO, YARA INTERNATIONAL

Table 2. Breakdown of economic activities according to the EU Taxonomy classification by Turnover, CAPEX and OPEX (mean and standard deviations for activities expressed as mil EUR).

Taxonomy Activities	No. of obs	Turnover			CAPEX			OPEX		
		Total (mil EUR)	Average %	Std. Dev	Total (mil EUR)	Average %	Std. Dev	Total (mil EUR)	Average %	Std. Dev
Total Aligned A1	19	5,668	298	676	1,379	72	137	1,038	54	144
Total Non-Aligned A2	19	20,252	1,063	2,025	3,190	180	245	1,945	133	215
Total Eligible A1+A2	19	25,915	1,363	2,240	4,569	240	314	2,984	155	227
Non-Eligible B	19	167,143	8,797	14,164	13,249	697	1,205	13,267	698	1,275
TOTAL A+B	19	192,937	10,154	15,958	17,828	938	1,474	16,222	853	1,425

Source: Author's own calculation with R software based on data collected from annual reports of chemical companies.

In terms of turnover, aligned activities (A1) account for 5,668 million EUR, which is equivalent to 3.89% on average, from the turnover reported by the targeted chemical companies. Significantly more revenue is generated by non-aligned operations (A2), which amount to 20 billion EUR accounting for 9% of the overall turnover. In the realm of corporate finance, capital expenditure, often known as CAPEX, continues to be one of the most important indications of a company's investment strategy, future orientation, and dedication to certain business operations. The analysis of the supplied data on CAPEX related to eligible vs non-eligible and aligned versus non-aligned operations provides profound insights into the goals and foresight of the chemical sector. In terms of investment patterns related to capital expenditure (CAPEX), eligible activities account for almost 25% of the total CAPEX reported. This may be an indication that these businesses are increasing their investments in eligible operations, pointing to the possibility of a shift or expansion in this area in the near future. Within the eligible activities, the non-aligned activities (A2) get a substantially larger investment (17%) than their aligned counterparts (A1), which only account for 7% of CAPEX. Given these numbers, we can state that there is still room for improvement for chemical companies to shift their investments towards more sustainable activities according to the EU taxonomy. It is worth mentioning that chemical businesses are one of the most difficult industries to transform because of its extensive processes, complex supply networks, and established operating models. As a result, the chemical industry is one of the least likely to see significant changes in their processes and operations towards more sustainable activities. During their existence on the market, chemical businesses have made significant investments in the infrastructure or perfecting the chemical processes necessary to be competitive. Plants, refineries, and factories are often planned long term and tend to be rigid in face of new challenges and regulations on the market. In certain situations, the switch to more environmentally friendly business practices, could require the modernization of their current facilities, change the operation model or simply undergo a digital transformation to be able to measure and follow up on their sustainability strategy. The resources engaged in this process are complex and often requires a change in mindset and organizational culture of the company.

Operational Expenses (OPEX) offers a glimpse into the continuing expenditures that are connected to the day-to-day operations of a business. It provides an overview of how companies manage their day-to-day operations and the many directions in which resources are being directed. With an operational cost that only accounts for almost 6% of the overall OPEX, the operational expenses for aligned activities appear to have the same pattern as turnover and OPEX. Almost 6% are reported as aligned while non-aligned activities account for almost 15%, more than double compared to the ones considered sustainable.

The share of non-eligible activities accounts for a staggering 80% of the total OPEX. This suggests that these processes continue to serve as the fundamental basis for the day-to-day operations of the chemical industry. Even while non-eligible operations dominate the operational landscape of today, organizations are likely going to feel increased pressure from regulatory authorities, stakeholders, and market dynamics to optimize the OPEX of eligible activities even more. Businesses might make investments in technology and procedures that reduce the ongoing costs of operating in a sustainable manner, so making their operations not only more beneficial to the environment but also more economically competitive. One important aspect to mention is that the share of aligned, non-aligned and not eligible will not always sum

up to 100% as during the data extraction and processing the percentages associated to low levels activities will not reflect the accurate decimals in the percentages. This is also due to the unit in EUR used in the Taxonomy tables which varies from millions to thousands.

We have looked at the share of eligible, aligned and not aligned activities for each KPI for the entire data sample od companies analyzed. The EU Taxonomy regulation mandates the companies to assess each activity individually and report on their alignment or eligibility. The regulation has clear guidelines on the technical screening criteria to evaluate if an activity is sustainable or not, it is always linked to an objective and to an activity sector.

Table 3. Breakdown of activities by objective and reported KPI in EUR absolute value.

Activity	Objective	Turnover	CAPEX	OPEX
Aligned A1	Climate Mitigation	5,667,559,799	1,378,984,186	1,038,088,791
	Water		4,600	
Non-Aligned A2	Biodiversity		16,641	
	Circular Economy	15,700,000	4,324,499	5,900,000
	Climate Mitigation	20,197,702,485	3,183,239,006	1,897,934,321
	Pollution Prevention	38,500,000	831,645	41,160,305
	Water		258,574	

Source: Author's own calculation based on annual reports of chemical companies.

Table 3 details the breakdown of activities linked to the objective that is targeting. Most activities reported by the chemical companies are mitigating against climate change and a large share are not aligned according to the EU Taxonomy principles. In particular, the highest amount is accounted for Turnover with 20 billion EUR that is not aligned vs 5 billion EUR aligned activities. It seems that chemical companies are investing heavily in climate related projects to reduce their impact on the environment and reduce their carbon footprint. CAPEX and OPEX activities are lower in amount but still are not aligned. On the other end, Water and Biodiversity account for the smallest share in terms of tackled objectives. This might be due to the fact that these activities are not directly generating revenues and companies are not making them a priority in their sustainability strategy. Circular Economy and Pollution Prevention have relatively modest shares for the three KPIs reported, accounting for more than 54 million EUR for Turnover, 5 million EUR for CAPEX and 47 million EUR for OPEX for both aligned and not aligned activities. This shows that chemical companies are willing to explore the different solutions linked to circular economy and potentially to be aligned to the EU Taxonomy principles.

The European Commission provides an indicative mapping of the economic activities reported and how these could be linked to NACE activity codes. We have used the indicative mapping of these activities to understand in what sectors the chemical companies chose to deploy their activities. Figure 1 depicts the aligned and not aligned activities that are linked to turnover. Most of the activities are concentrated in the manufacturing sector, followed by energy, water and waste management systems and transportation. As already seen from the previous data insights, most activities are not aligned according to the EU Taxonomy criteria. Table 4 provides more detailed information related to the aligned activities that are linked to Turnover. Most chemical companies generate their sustainable revenues in 2023 from the manufacturing of soda ash, manufacture of low carbon technologies and manufacture of batteries. Although the share of these activities is not high compared to the total of activities reported, we can see that chemical companies have started exploring other markets from where they can generate green revenues and where the demand for more sustainable products is increasing. As chemical companies act as suppliers for other industries, we could see an increase in green revenues in the upcoming years as market trends shifts and consumers become more aware of the impact on environment.

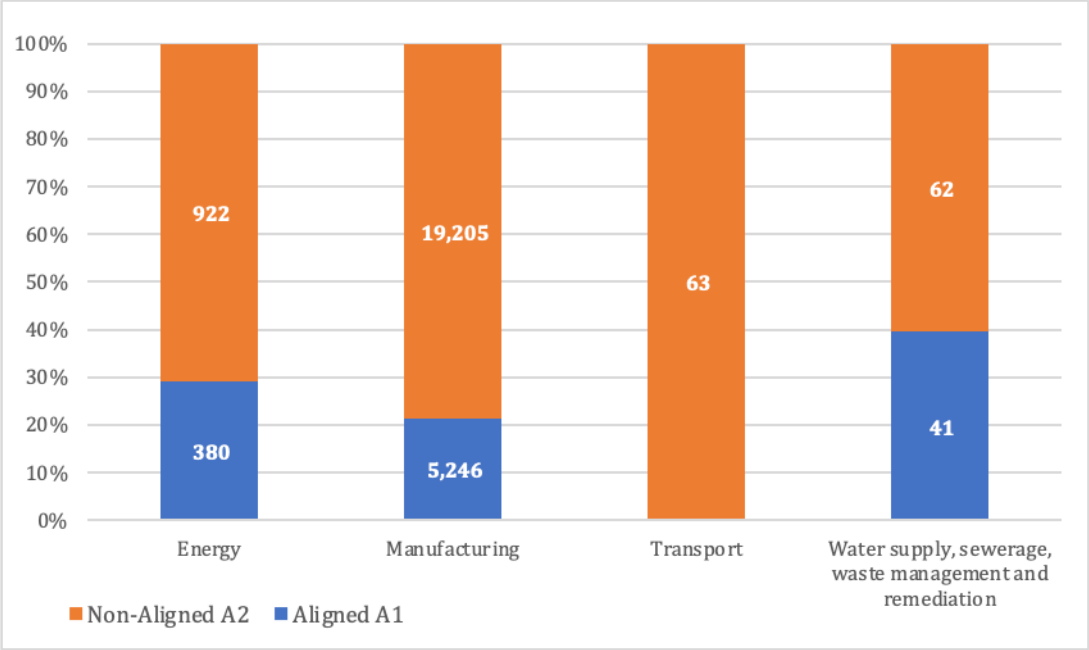

Figure 1. Aligned and Not Aligned activities linked to Turnover reported by chemical companies (absolute value in mil EUR and percentage of Eligible activities).
Source: Author's own calculation based on annual reports of chemical companies.

Table 4. Breakdown of Aligned activities by sector and reported Turnover (expressed in EUR absolute value and as a percentage of Eligible activities).

Activity Sector and Activity Code and Name	EUR	%
Energy	**380,479,000**	**1.47%**
4.13 Manufacture of biogas and biofuels for use in transport and of bio-liquids	377,500,000	1.46%
4.5 Electricity generation from hydropower	2,979,000	0.01%
Manufacturing	**5,246,380,799**	**20.24%**
3.10 Manufacture of hydrogen	68,800,000	0.27%
3.12 Manufacture of soda ash	2,113,000,000	8.15%
3.13 Manufacture of chlorine	80,000,000	0.31%
3.14 Manufacture of organic basic chemicals	200,000,000	0.77%
3.16 Manufacture of nitric acid	21,620,000	0.08%
3.17 Manufacture of plastics in primary form	162,503,926	0.63%
3.2 Manufacture of equipment for the production and use of hydrogen	31,800,000	0.12%
3.3 Manufacture of low carbon technologies for transport	52,300,000	0.20%
3.4 Manufacture of batteries	861,956,873	3.33%
3.5 Manufacture of energy efficiency equipment for buildings	32,000,000	0.12%
3.6 Manufacture of other low carbon technologies	1,622,400,000	6.26%
Water supply, sewerage, waste management and remediation	**40,700,000**	**0.16%**
5.10 Landfill gas capture and utilization	13,200,000	0.05%
5.7 Anaerobic digestion of bio-waste	27,500,000	0.11%

Source: Author's own calculation based on annual reports of chemical companies.

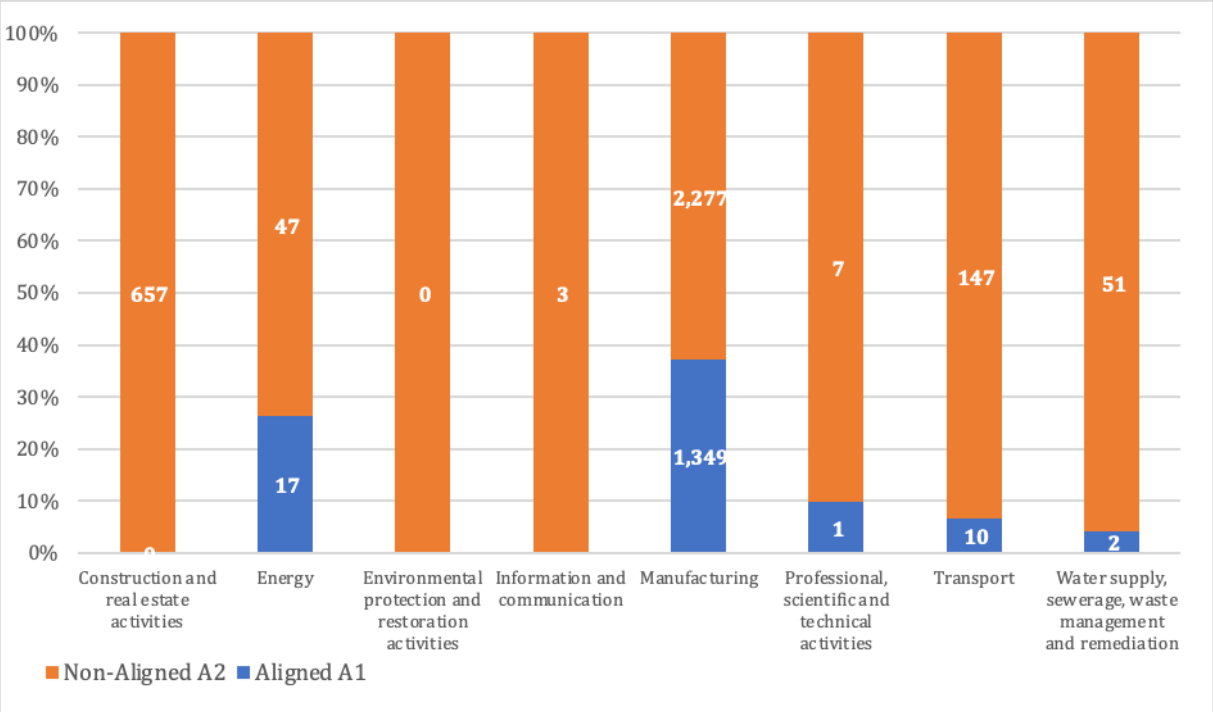

Figure 2. Aligned and Not Aligned activities linked to CAPEX reported by chemical companies (absolute value in mil EUR and percentage of Eligible activities).
Source: Author's own calculation based on annual reports of chemical companies.

With respect to CAPEX, we see more sectors in which the companies are willing to concentrate their investments. The largest share is represented by the manufacturing sector accounting for more than 3.5 bn EUR, followed by construction and real estate activities with 657 million EUR and transportation with 157 mil EUR. As depicted in Figure 2, most of the activities reported are not aligned and they do not fulfill the criteria set out in the EU Taxonomy regulation. In terms of aligned activities, we notice that companies were willing to make green investments in low carbon technologies (395 million EUR), manufacture of hydrogen (327 million EUR) and manufacture of batteries (244 million EUR). This is consistent with the data reported on turnover. Chemical companies increased their investments in 2023 especially in the manufacturing of hydrogen to develop their operations and generate additional revenues in the following years. Apart from the manufacturing activities, Table 5 shows companies invested in the renovation of existing buildings and in the manufacturing of biogas and storage of hydrogen. These green investments in energy accounted for more than 16 mil EUR at the end of 2023 for the companies in the data sample. We also notice investments in low carbon road transport accounting for more than 9 million EUR and in the water and waste management systems for more than 2 million EUR. It seems that sustainable R&D activities were intensified as companies are willing to invest in IT technologies that would help them reduce their carbon footprint.

Table 5. Breakdown of Aligned activities by sector and reported CAPEX (expressed in EUR absolute value and as a percentage of Eligible activities).

Activity Sector and Activity Code and Name	EUR	%
Construction and real estate activities	**23,722**	**0.00%**
7.2 Renovation of existing buildings	23,722	0.00%
Energy	**16,550,000**	**0.36%**
4.12 Storage of hydrogen	4,500,000	0.10%
4.13 Manufacture of biogas and biofuels for use in transport and of bio-liquids	10,700,000	0.23%
4.16 Installation and operation of electric heat pumps	50,000	0.00%
4.25 Production of heat/cool using waste heat	1,300,000	0.03%

Manufacturing	**1,349,205,078**	**29.53%**
3.10 Manufacture of hydrogen	327,600,000	7.17%
3.12 Manufacture of soda ash	260,000,000	5.69%
3.13 Manufacture of chlorine	23,000,000	0.50%
3.14 Manufacture of organic basic chemicals	13,000,000	0.28%
3.15 Manufacture of anhydrous ammonia	21,620,000	0.47%
3.16 Manufacture of nitric acid	47,940,000	1.05%
3.17 Manufacture of plastics in primary form	13,035,078	0.29%
3.2 Manufacture of equipment for the production and use of hydrogen	2,600,000	0.06%
3.4 Manufacture of batteries	244,210,000	5.35%
3.5 Manufacture of energy efficiency equipment for buildings	1,000,000	0.02%
3.6 Manufacture of other low carbon technologies	395,200,000	8.65%
Professional, scientific and technical activities	**707,386**	**0.02%**
9.2 Research, development, and innovation for direct air capture of CO2	700,000	0.02%
9.3 Professional services related to energy performance of buildings	7,386	0.00%
Transport	**10,340,000**	**0.23%**
6.10 Sea and coastal freight water transport, vessels for port operations and auxiliary activities	940,000	0.02%
6.15 Infrastructure enabling low-carbon road transport and public transport	9,400,000	0.21%
Water supply, sewerage, waste management and remediation	**2,158,000**	**0.05%**
5.10 Landfill gas capture and utilization	300,000	0.01%
5.4 Renewal of waste water collection and treatment	258,000	0.01%
5.7 Anaerobic digestion of bio-waste	1,600,000	0.04%

Source: Author's own calculation based on annual reports of chemical companies.

In terms of OPEX, companies reported most activities linked to the manufacturing sector as this is their main domain of activity. Transportation related activities, energy and water supply account for the majority of eligible activities according to the EU Taxonomy.

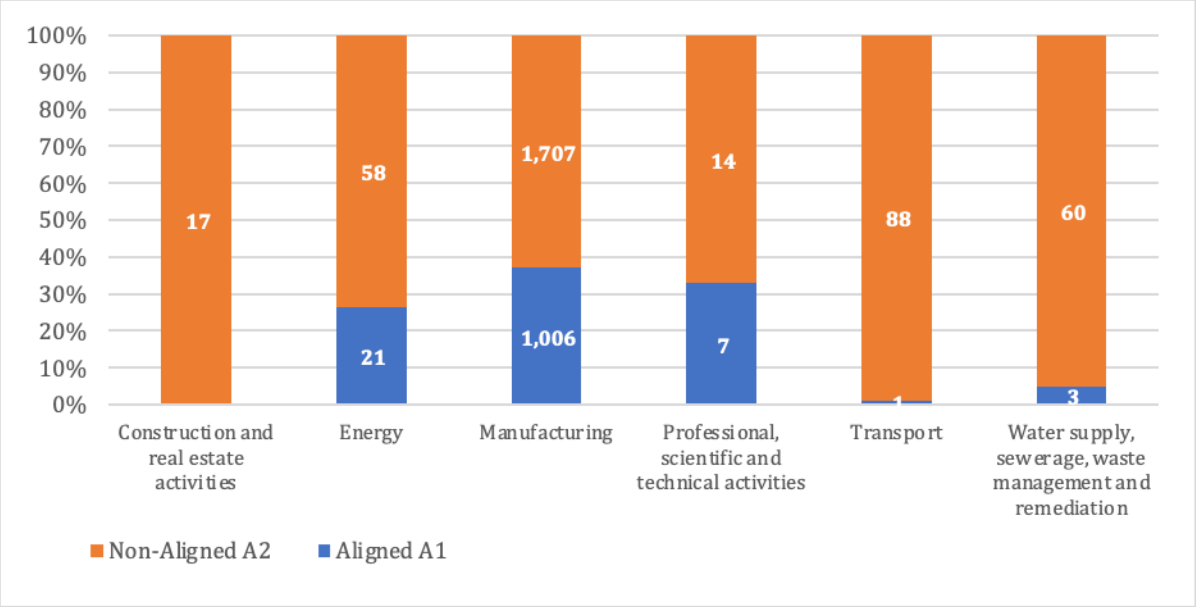

Figure 3. Aligned and Not Aligned activities linked to OPEX reported by chemical companies (absolute value in mil EUR and percentage of Eligible activities).
Source: Author's own calculation based on annual reports of chemical companies.

Table 6. Breakdown of Aligned activities by sector and reported OPEX (expressed in EUR absolute value and as a percentage of Eligible activities).

Activity Sector and Activity Code and Name	EUR	%
Energy	**20,720,000**	**0.69%**
4.13 Manufacture of biogas and biofuels for use in transport and of bio-liquids	20,300,000	0.68%
4.5 Electricity generation from hydropower	420,000	0.01%
Manufacturing	**1,006,228,791**	**33.72%**
3.10 Manufacture of hydrogen	9,300,000	0.31%
3.12 Manufacture of soda ash	610,000,000	20.44%
3.13 Manufacture of chlorine	19,000,000	0.64%
3.14 Manufacture of organic basic chemicals	41,000,000	1.37%
3.16 Manufacture of nitric acid	35,720,000	1.20%
3.17 Manufacture of plastics in primary form	22,308,791	0.75%
3.2 Manufacture of equipment for the production and use of hydrogen	38,500,000	1.29%
3.3 Manufacture of low carbon technologies for transport	8,700,000	0.29%
3.4 Manufacture of batteries	27,000,000	0.90%
3.5 Manufacture of energy efficiency equipment for buildings	3,000,000	0.10%
3.6 Manufacture of other low carbon technologies	191,700,000	6.42%
Professional, scientific and technical activities	**7,000,000**	**0.23%**
9.2 Research, development, and innovation for direct air capture of CO2	7,000,000	0.23%
Transport	**940,000**	**0.03%**
6.10 Sea and coastal freight water transport, vessels for port operations and auxiliary activities	940,000	0.03%
Water supply, sewerage, waste management and remediation	**3,200,000**	**0.11%**
5.10 Landfill gas capture and utilization	700,000	0.02%
5.7 Anaerobic digestion of bio-waste	2,500,000	0.08%

Source: Author's own calculation based on annual reports of chemical companies.

Related to the specific activities depicted from the annual reporting, we gather that companies continue on their strategy to manufacture sustainable soda ash, a product used mostly in the production of glass, powdered detergents and soaps, cleaning and water treatment. Around 20% of reported soda ash manufacturing are aligned and account for more 600 million EUR for the entire data sampled analyzed. The same picture applies for OPEX breakdown. Operational expenses of chemical companies refer to the production of biogas and biofuels, manufacture of hydrogen and low carbon technologies.

5. DISCUSSION

Through this research we attempted to have a first insight into the EU Taxonomy reporting of chemical companies. The objective was to understand where sustainability stands from a strategic perspective and how the industry is preparing to reduce their environmental impacts. The findings suggest that the industry has started a transformation process fostering sustainability but there is still a long way to achieve maximum results. Our findings can be coupled with the PWC reports (PWC, 2023; PWC, 2024) in terms of reporting as most of the chemical companies in the data sample report their data using the template provided by the European Commission. Our data analysis reflects that a low share of activities is eligible and even a lower one is aligned according to the principles of the EU Taxonomy. This is observed across the three indicators reported, turnover, CAPEX and OPEX. As it was expected, the majority of activities are linked to manufacturing but we also observed that some revenues are generated by the sustainable manufacturing of soda ash, low carbon technologies and biofuels. The percentage is still small compared to the amount of eligible activities that could be sustainable if sufficient efforts are made

towards improving their processes. We next expose and analyze the reasons why a higher degree of sustainability is difficult to achieve among the chemical companies.

5.1. Operational complexities

The difficulty in achieving a higher share of alignment raises from the fact that the chemical sector tends to be more complex and specific than other industries. Chemical processes have been established and perfected over the course of many years as a consequence of extensive study, specialized knowledge, and repeated experimentation (Wangthong & Rojniruttikul, 2023). Altering these processes so that they are less harmful to the environment is not as simple as exchanging one component for another or rearranging the order in which certain steps are carried out. It may need a complete rethinking of the procedure, which brings with it a wide range of technical obstacles as well as the possibility of a lower production or lower overall product quality. Here comes in play, the dependence of chemical companies on raw materials. Many different chemicals are produced from non-renewable raw materials such as petroleum, which creates a dependency on these resources. To successfully make the switch to bio-based or more environmentally friendly raw materials, it is not enough to just identify a suitable alternative. The company also needs to establish that this alternative can be acquired on the required scale and without lowering the quality of the final product. Despite the fact that most chemical companies are research oriented, this does not mean that they can easily modify their recipe to include biobased raw materials.

Furthermore, even if a chemical firm is completely dedicated to the concept of sustainability, it frequently operates inside a complex network of processes and products that are dependent on one another. It is possible for a single primary product to generate many by-products, which can then be used as raw materials in other processes. Altering one process or input in the interest of sustainability can throw off the production of another essential good. Therefore, establishing sustainability is not a step-by-step process but rather a complex process with many dimensions. Moreover, it is possible that the company's suppliers and distributors are not aligned on sustainable practices or do not have the resources necessary to maintain sustainable operations. For instance, a business that is interested in acquiring environmentally friendly raw materials may discover that there are just insufficient vendors that satisfy the requirements. Given the possible negative effects that its operations might have on both the environment and people's health, the chemical industry is one of the most strictly regulated industries. When new procedures or materials are utilized, it is possible that they may require re-certification, re-approval, or rigorous testing in order to guarantee that they are in accordance with both local and international standards. This not only mean that the shift to more sustainable raw materials or commercial products might take longer, but it also adds another degree of complexity and an additional expense. By the same token we could also argue that companies are more incentivize to rethink their long-term strategy in the light of the EU taxonomy and the future CSRD compliance. This is coupled with the financial sector legal incentives to connect their lending strategies with sustainable practices because to the EU Taxonomy and other efforts of a similar nature that are being implemented throughout the world.

Although the majority of the analysed companies declare and state on their website that they are committed to decrease emissions, focus on circular economy and empower local communities with new skills, the findings of this research tell us otherwise. It seems that there is a significant gap between these declarations and the actual activities performed. More than half of the eligible activities are not aligned. This disparity highlights the difficulties that have been encountered by businesses in the process of putting their sustainable aspirations into action. The absence of alignment in key activities shows that either the execution of these strategies is trailing behind or that the requirements of the taxonomy are regarded as being too difficult or restrictive for firms to completely comply with. One possible solution to close this gap is for them to start measuring their real impact on the environment and based on the results to set up realistic objectives that are in line with their capacity of implementation. For these reasons, data management systems and data governance can become extremely important for their long-term sustainability strategy. Multinationals, especially renowned chemical companies can have complex data architecture and find it difficult to have accurate data important for decision making process.

5.2. Regulatory pressures

Other difficulties for chemical companies to transform their daily operations include regulations and the perception of the public. Regulations controlling the production of chemicals have gotten more stringent in response to the growing environmental awareness across the globe. Although these restrictions are necessary for moving the sector in the direction of sustainability, they may also provide difficulties, particularly for businesses that operate in a number of different jurisdictions, each of which has its own set of laws. Because of the fluid nature of the regulatory environment, staying ahead of the curve or even just being compliant may be an expensive endeavor, particularly for more novice competitors in the market. There is evidence that heavy polluting chemical companies may feel less prone to make green investments in face of enforced environmental regulations (Zou et al., 2022). While there is an increasing demand for environmentally friendly products, there is also a consistent market sector that places a higher priority on cost than sustainability. Chemical businesses need to find a middle ground between meeting the needs of the current customer base and developing products with an eye towards the future. Completely changing their business model might turn off a substantial number of the customers they already have. In addition, the general public frequently has an unfavorable impression of the chemical industry due to the sector's tendency to be stereotyped. The problem at hand is not just one of a technical or financial nature, but also one of reputation. The process of transforming operations to be more sustainable can help in redefining this impression, but the path is a lengthy one, and throughout this transformation, the industry is frequently subjected to more criticism than praise.

Another finding is related to the use of significant capital expenditures (CAPEX) in the manufacture of hydrogen, soda ash, batteries and low carbon technologies. Hydrogen production is a leading renewable energy alternative because it can decarbonize heavy industries, transportation, and power generation. These might be the reasons why chemical corporations decided to undergo considerable investment in this alternative. Green or blue hydrogen produced from renewable energy or carbon capture has clean fuel properties. By investing in hydrogen manufacture, chemical firms can address the expanding need for hydrogen in fuel cells, industrial heating, and ammonia production. This is in line with the evidence that more companies want to position themselves on the hydrogen market (Eltweri et al., 2024). Moreover, our findings also suggest that green investment in the production of batteries and low carbon technologies are evidence that chemical industries are not only addressing an increasing market demand for these new technologies but also fostering the development of new capabilities like better efficiency, capacity of storage and sustainability. This evidence is supported by other studies like Chen (2024) where Chinese companies are actively working to be competitive in the batteries market with the support of policy incentives and continuous investment in the development of the technology. The investment of chemical corporations in the manufacture of batteries implies that these businesses are investigating the possibility of diversification. Even if many of the activities reported do not fit with the EU taxonomy criteria, high CAPEX linked to the investment in batteries can indicate a shift towards technologies that are more environmentally friendly.

Apart for the increased demand of batteries the automotive industry also needs lighter materials to cut high emissions, improve the energy efficiency of their vehicles and keep up with the market demands of consumers. In this area chemical companies should make a priority the manufacture of sustainable plastic products that would lead to lower footprint and increased demand from the automotive industry. This is backed up by Kamińska-Witkowska and Kaźmierczak (2024) and Carvalho et al. (2024) research as the automotive industry is interested in using more sustainable raw materials in their production process. To keep encouraging diversification within the chemical sectors, public policies should strive for developing a clear regulatory framework for growing businesses that prioritizes sustainability and green sources of energy. From our findings we see that companies lack CAPEX and OPEX in regenerable sources and incentives from governments would foster development towards these activities. Another idea would be to increase financing for public-private research partnerships that are focused on sustainable chemical processes, waste minimization, and the concepts of circular economies. The establishment of innovation hubs (Sgroi & Marino, 2021; Egessa & Mwadzogo, 2024) or clusters is one way to further encourage cooperation between existing chemical industries, newly founded businesses, and academic institutions. Our results indicate that there is still room for improvement in incurring CAPEX in the field of research and development in carbon capture technologies that would foster the development of new green

products with a lower carbon footprint. The activities related to the manufacture of soda ash seems to account for high level of aligned CAPEX and could possibly be linked to its increased demand in the production of energy efficiency glass.

Among the lowest share of aligned activities, we remind of the renovation of existing structures belonging to chemical companies. This is an indication that companies are willing to modernize their facilities but there is still room for improvement in order to have higher alignment according to the EU taxonomy principles. To this end, public policy initiators should focus on providing financial assistance in the form of grants or interest-free loans to businesses who invest in the renovation of their existing properties in order to increase the energy efficiency of their operations or to include renewable energy sources. These kinds of proposals would lower the environmental footprint that chemical factories leave behind, and it may lead to considerable reductions in greenhouse gas emissions, and align to the EU's climate objectives and SDGs. Regulators should also consider the cost of disclosure as companies need to incur important costs in external consultancy to understand how the EU Taxonomy needs to be implemented. Coupled with future CSRD disclosure, these regulatory pressures might deter companies from focusing on their competitiveness and innovation as important resources might be focused on compliance rather on the core business of the company. By this token, the European Commission should assess whether the cumulative load of disclosure obligations has a negative influence on the performance of European firms. In fact, this may result in a reduction of their competitive advantage in comparison to overseas competitors that are not subject to equivalent regulatory demands. The complexity of these regulations could undermine the existence of European companies in industries that are essential to the growth and sustainability of the economy. In this particular setting, the Draghi report on European competitiveness suggests that the EU Taxonomy should be simplified, this given the fact that the technical screening criteria might evolve in the future. Simplification can be the key to produce more positive results. If the framework were simplified, it would minimize the administrative complexity and the expenses associated with compliance, which would allow businesses to better concentrate their resources toward innovation and market performance. A balance needs to be achieved between environmental transparency and maintaining the competitiveness of European companies.

6. CONCLUSIONS

The data collected on a limited sample chemical companies subject to EU taxonomy presents a non-exhaustive overview of the financial operations, that are aligned or not aligned to the EU taxonomy criteria. Our findings provide a glimpse into the economic goals and strategic investments of the chemical sector. Our research shows that sustainable activities make up just a tiny portion of the total turnover and capital expenditure (CAPEX) in the chemical industry. This emphasizes the need for considerable progress in aligning investments with sustainable practices. This study not only enhances the comprehension of how business actions within the EU Taxonomy might impact sustainable development but also demonstrates the significance of technology in enhancing data collecting and analysis procedures for improved compliance and reporting.

Despite the good trend, the move to sustainable practices faces major obstacles. These problems include budgetary restrictions, the complexity of legal requirements, and operational impediments. It is common for businesses to confront significant expenses associated with the adoption of new technology and processes, in addition to the fact that regulatory frameworks are always growing and requiring rigorous compliance efforts. In addition, the possibility of greenwashing, which is the act of misrepresenting efforts to promote sustainability, creates reputational concerns in a market that is becoming increasingly dubious. The complexity of the regulatory disclosures adds another layer of difficulty to the whole process. The EU Taxonomy includes stringent screening requirements that companies are required to fulfill in order to be allowed to identify their operations as sustainable. The navigation of this framework requires a large amount of administrative effort and skill, despite the fact that it gives clarity and uniformity in the definition of sustainable activities. Adapting to ever-changing rules is a must for businesses, since these requirements frequently necessitate the modification of internal procedures, systems, and reporting methods. These adjustments may be both expensive and time-consuming. Additionally, operational constraints are a barrier to advancement. A significant number of chemical businesses are active in industries that have long-standing procedures and infrastructure that

are difficult to modify in order to conform to sustainability recommendations. Redesigning manufacturing lines, locating new resources, and reevaluating supply chains are frequently associated with the process of transitioning to activities that are more environmentally friendly. Existing workflows may be subject to disruption as a result of this, which may necessitate significant personnel retraining and organizational reorganization.

In addition to these problems, there is a growing worry around greenwashing. This occurs when businesses may exaggerate or misrepresent their efforts to save the environment in order to satisfy the expectations of the market or of stakeholders. In a market that is becoming more suspicious, investors, consumers, and regulators are demanding genuine and demonstrable contributions to sustainability. This generates reputational concerns, particularly in a market that is becoming increasingly skeptical. By this token, transparency and accountability are becoming more important than they have ever been, and businesses that fail to support their assertions with trustworthy data may be subject to criticism. In order to effectively address these difficulties, it is necessary for politicians, corporations, and other stakeholders to collaboratively develop strategic solutions. Policymakers at both the EU and member state levels are tasked with the responsibility of formulating and refining policies that strike a balance between fostering economic growth and maintaining environmental guardianship. Companies can be encouraged to engage in environmentally friendly technology and practices by providing them with financial incentives such as grants, subsidies, and tax cuts. At the same time, laws that are both clear and consistent may offer businesses with the direction they require to make decisions that are well-informed without being overpowered by the uncertainty that comes with regulatory compliance.

Partnerships between the public sector and the commercial sector can also speed up the transition to sustainability. The integration of renewable energy sources, carbon capture and storage and the generation of hydrogen are all examples of large-scale initiatives that might benefit from collaborations involving governments, research institutions, and industry partners. These collaborations serve to stimulate innovation, share risks and concentrate efforts and resources. Additionally, these types of alliances may facilitate the exchange of information and best practices, allowing businesses to gain insight from the achievements and difficulties of one another. In addition, the incorporation of sustainability measures into the culture of a company is very necessary for long-term success. When it comes to strengthening brand reputation, attracting investment, and appealing to consumers who are environmentally sensitive, businesses need to grasp the strategic importance of sustainability. This goes beyond simply complying with regulations. There is the potential to cultivate a culture of creativity and dedication to sustainable growth through the implementation of internal training programs, leadership that is focused on sustainability, and clear communication of goals.

As a conclusion, despite the fact that the chemical sector has made tremendous progress in conforming to the standards of the EU Taxonomy, major hurdles still exist. Progress is hampered by a number of obstacles, including financial limits, the complexity of legal requirements, operational obstacles, and the possibility of greenwashing. On the other hand, these difficulties also create chances for creative partnerships and cooperative endeavors. Accelerating the transition toward sustainability in the chemical sector may be accomplished via the utilization of technology, the cultivation of partnerships, and the alignment of legislative frameworks with the aims of sustainable development. This will ensure both economic resilience and environmental responsibility in the years to come. As future research topics one might investigate if the the EU Taxonomy regulation has the intended purpose of increasing sustainable growth or it affects negatively the revenues generated by companies and the prosperity of the European countries long term. Studies of this nature might investigate the dual impact on the regulation, which includes its efficiency in directing money toward activities that are environmentally sustainable as well as the possible trade-offs that it may have in terms of performance, innovative power and competitiveness. Additionally, one can analyse the comparative advantage or disadvantage that European companies subject to the EU Taxonomy have in the international market, particularly when competing against other companies operating in countries that have less severe regulations for sustainability reporting. By the same token, one could investigate if the regulation encourages the development of new green technologies or it restricts the dynamic nature of the economy by imposing rigid policies. By addressing these aspects, future research might give significant insights into improving the balance between legislative aims and

economic realities, ensuring that sustainability goals are accomplished without sacrificing the long-term resilience and profitability of European economies.

Acknowledgments
The author thanks to the reviewers for their valuable comments.

Use of AI tools declaration
The author declares they have not used Artificial Intelligence (AI) tools in the creation of this article.

Conflicts of interest
The author declares no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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