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Two sides of the same coin: Green Taxonomy alignment versus transition risk in financial portfolios[☆]

Lucia Alessi[a,b,*], Stefano Battiston[c,d]

[a] European Commission-Joint Research Centre, Italy
[b] CefES – Center for European Studies (Universitá degli Studi di Milano-Bicocca), Italy
[c] University of Zurich, Switzerland
[d] Ca' Foscari University of Venice, Italy

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ABSTRACT

We develop the first top-down method to estimate the greenness of financial portfolios, in terms of alignment to the EU Taxonomy for sustainable activities. We also develop a method to estimate, at the same time, the portfolio exposure to climate transition risk. We provide sector-level, standardized and transparent coefficients for both estimates, based on definitions of greenness and transition risk that are applicable across countries. We analyse the portfolios of Euro Area investors in 2022, based on the confidential Securities Holdings Statistics of the European Central Bank. We find that, overall, the greenness of Euro Area investors' portfolios is lower than their exposure to transition risk (2.8% vs. 11.7%).

Across financial institutions, we estimate greenness and exposure to transition risk, respectively, at 3.2% and 12% for investment funds, at 0.8% and 5% for banks and at 4.8% and 15.1% for insurers. Our analysis also shows that investors with large amounts invested in green activities can have at the same time large exposures to transition risk.

1. Introduction

While there is a flourishing literature on "green finance", most studies take for good the definition of "green" they get from this or that label and focus on other aspects, e.g. on the motives of investors to go green (Berrou et al., 2019). Few papers investigate the impact of different measures of greenness (see e.g. Alessi et al., 2021b; Hyun et al., 2020; Mumtaz & Yoshino, 2021). In contrast, to our knowledge there is no scientific literature investigating how to measure "greenness" in a replicable and transparent way, and how much of financial investment can actually be considered green.

One category of green assets are green bonds, with cumulative green bond market volume standing at USD 1.7 tn in 2022 Q1,[1] thus a small outstanding amount compared to global financial assets. Green bond certification schemes are qualitative frameworks whereby a particular issuance either satisfies the requirements, and is therefore labelled as 'green', or does not. As such, green bond certification schemes provide a binary classification of bonds, not a means to assess their various shades of green. They also do not necessarily certify that all bond proceeds are used to finance green activities. Moreover, only a fraction a green bonds are certified by third parties. Finally, there are several green bonds certification frameworks, the two main ones known as the Green Bond Principles (GBP) and the Climate Bond Initiative (CBI), which differ in criteria. Despite these limitations, the share of green bonds in a portfolio is often used to measure the greenness of the portfolio.[2] Another approach to assess the greenness of financial assets has been to focus on the E (Environmental) component of the ESG score (or rating) of the counterparty of the asset (Alessi, Ossola et al., 2021). This approach has the advantage to cover potentially all financial instruments (i.e. loans, bonds and equity). However, ESG scores differ across sustainability data providers (Berg et al., 2022; Billio et al., 2020), they tend to be based on self-reported data and qualitative features (e.g. "does the firm have a policy for climate change?"). With focus on the climate dimension of greenness, several works use as a proxy the GHG emissions, e.g. lower emission intensity implies higher

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* Correspondence to: European Commission – Joint Research Centre. Via Enrico Fermi, 2749, Ispra (VA), Italy.
E-mail addresses: lucia.alessi@ec.europa.eu (L. Alessi), stefano.battiston@uzh.ch (S. Battiston).

1 Source: Climate Bonds Initiative, Sustainable Debt Market Summary Q1 2022.

2 For example, various existing ecolabels as well as the proposed EU Ecolabel for financial products can be awarded to bond funds only if they invest in a large enough share of green bonds.

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greenness (Alessi, Battiston et al., 2021; Bolton & Kacperczyk, 2021). However, this approach may overlook that firms' emissions can only be compared within sectors of activities (e.g. the emission intensity of a bank is not comparable to that a steel manufacturer).

A key recent development that aims to bring clarity on these issues and transparency on the market, has been the adoption of the EU Taxonomy for sustainable activities, which provides replicable criteria for greenness based on international standards for the classification of economic activities as well as on measurable GHG emission thresholds. It aims to cover all aspects of sustainability, but so far it has been developed with a focus on climate (see more details in Section 2). However, the application of the EU Taxonomy approach requires to have information on the technological characteristics, energy efficiency and/or GHG emission intensity of individual firms, which is currently scarce.

Moreover, all these approaches, do not provide explicit information on transition risk, i.e. the financial risk associated with activities that are incompatible with a low carbon economy (Dunz et al., 2021; Roncoroni et al., 2021). Indeed, a challenge is that, even assuming to be able to measure greenness, two portfolios with the same level of greenness could include investments into firms with very different levels of transition risk. For instance, for a firm in the extraction of coal it could be more difficult to align its activity to climate targets as compared to a firm in the manufacturing of light duty vehicles, which has the possibility to turn to electric vehicles. Should a firm not be willing or able to transition, it could face stranded assets, higher costs, reputational issues, or even regulatory ones. On regulatory risk, in particular, Seltzer et al. (2022) show that polluting firms tend to have lower credit ratings and higher yield spreads, particularly when their facilities are located in states with stricter regulatory enforcement. This means that for a given level of environmental performance or carbon footprint, some firms may be more exposed to regulatory risk than others. For completeness, one should also consider that firms may also be exposed to the so-called climate physical risk, i.e. the risk of financial losses due to climate-related disasters becoming more frequent and more severe, and impacting, e.g. a company's plants or those of its suppliers (Bressan, Duranovic et al., 2022).

ESG scores could partially reflect the different exposure of companies to climate transition risk, but there is no consensus on how to translate the E score into a risk measure. Looking at GHG emissions only may also be sometimes misleading, as data availability is much better for scope 1 emissions, i.e. direct emissions, compared to scope 2 or 3 emissions; however, fossil fuel extraction is characterized by very low direct emissions. In order to overcome some of these limitations, a framework to classify financial assets on the basis of standard classification of economic activities, known as Climate Policy Relevant Sectors (CPRS) has been introduced in Battiston et al. (2017) and it has been applied by several policy making institutions (e.g. EBA, 2020; EIOPA, 2019). In particular, the CPRS classification allows to develop a rebalancing portfolio strategy to reduce transition risk (Bressan, Monasterolo et al., 2022).

Against this background, the contributions of our paper are as follows. First, we develop a method to measure the greenness of a financial portfolio in terms of the share of investments that are aligned to the EU Taxonomy for sustainable activities. To this end, we provide estimates of standardized Taxonomy alignment coefficients (TACs) for all economic sectors covered so far by the Taxonomy for the climate change mitigation objective. These coefficients allow to compute an aggregate level of Taxonomy Alignment of a portfolio (its overall greenness) based on amounts invested across the sectors of economic activity identified by NACE codes at 4 digits.[3] They can also be periodically updated to reflect market developments (e.g. the progressive greening of relevant economic sectors), as well as regulatory developments (e.g. the tightening of relevant Taxonomy screening criteria). This method can be applied to investments into firms even when information on the firm's compliance to the relevant criteria is not available, and has already been used in policy contexts (see e.g. EBA (2021), ESMA (2021) and ESRB (2021)) based on an earlier version documented as working paper in Alessi et al. (2019).

Second, because greenness does not provide a direct assessment of risk, we develop a method to measure the level of exposure to transition risk of a financial portfolio. Investments exposed to transition risk are identified in terms of a structured list of high-carbon activities. This measure complements in a consistent way the first one, as it applies on the same set of NACE sectors and provides standardized Transition-risk Exposure coefficients (TECs) reflecting the transition potential of each sector.

Both methods can be readily applied to any portfolio of financial investments, yielding results that are comparable and replicable across jurisdictions and time.

The two methods are best used together. Indeed, as a third contribution, we deploy them to analyse the portfolios of European investors based on confidential supervisory data obtained from the Securities Holdings Statistics of the European Central Bank. Based on 2022Q1 data and focussing on equities and corporate bonds issued by Euro Area resident firms, we estimate a greenness of about 2.8% for EU financial markets - a figure that would increase if further green activities are included in the Taxonomy under the objective of mitigation. Further, this figure is expected to increase over time as the economy gets more aligned with the EU climate mitigation objectives. At the same time, we estimate an exposure to transition risk of 11.7%. The greenness of Euro Area investors' portfolios is lower than their exposure to transition risk. In particular, greenness and transition risk are, respectively, 3.2% and 12% for investment funds, 0.8% and 5% for banks and 4.8% and 15.1% for insurers.

Overall, our work allows to disentangle and appreciate the interplay between greenness and transition risk in financial portfolios. A portfolio of financial assets is invested in a range of economic activities, some contributing to its overall greenness and some contributing to its transition risk exposure. As a result, a financial portfolio has simultaneously a level of greenness and a level of exposure to transition risk. These two numbers are not trivially the complement of each other and not necessarily sum up to 100. This means in particular that an investor could have a large amount invested in green assets and yet have large exposure to transition risk. Nonetheless an increased volume of green instruments is key to ensure that high-carbon counterparties proceed in their transition and hence decrease their exposure to transition risk.

The paper is structured as follows. Section 2 provides some policy background on the EU Taxonomy. Section 3 outlines the conceptual framework. In Section 4, we present our approach to estimating the greenness and the exposure to transition risk of financial portfolios, deriving sector-specific standardized coefficients. In Section 5 we describe the data and result of our empirical application on EU financial markets and investor's holdings. Section 6 concludes and discusses limitations and possible extensions.

2. Policy background

In a context in which attention towards sustainability, including the environmental impact of financial and non-financial corporates, is rapidly increasing, investors need tools to assess the greenness of their business. Besides reputational aspects, there are new legal obligations in the European Union, by which larger firms will soon need to disclose on the greenness of their activities. In the case of financial institutions, this basically means reporting on the greenness of their assets.

To overcome the lack of shared and replicable definition of green, the EU Commission has introduced the EU Taxonomy for sustainable economic activities. The Taxonomy is a classification tool for economic

[3] https://ec.europa.eu/eurostat/documents/3859598/5902521/KS-RA-07-015-EN.PDF.

activities which is structured around the following six environmental objectives: (i) climate change mitigation; (ii) climate change adaptation; (iii) sustainable use and protection of water and marine resources; (iv) transition to a circular economy; (v) pollution prevention and control; and (vi) protection and restoration of biodiversity and ecosystems. Economic activities are defined as 'green' if they provide a substantial contribution to at least one environmental objective, while at the same time do no significant harm to any other environmental objective. In order for these two conditions to be satisfied, an economic activity must fulfil a set of activity-specific technical screening criteria. Additionally, it needs to meet a set of minimum social safeguards.[4]

So far, technical screening criteria have been developed for the two climate objectives.[5] While discussion is still ongoing on some activities, the so-called "Climate Delegated Act" covers economic activities which are responsible for almost 80% of direct greenhouse gas (GHG) emissions in Europe. The technical screening criteria for the 'substantial contribution' (SC) and the 'do no significant harm' (DNSH) conditions are often stricter than the provisions of sectoral legislation, resulting in a very ambitious Taxonomy. This is because a science-based environmental sustainability assessment, taking a life-cycle approach with a long-term horizon, shows that often more stringent criteria are needed to reach the EU environmental goals. At the same time, the Taxonomy expands the green investable universe much beyond renewable energy, to include, for instance, activities that are considered as enabling the low-carbon transition, thus covering a broad range of sectors from manufacturing, to transport, buildings, and many others. This is a key characteristic of the Taxonomy, as it allows environmentally-minded investors to diversify their portfolios.

Against such a definition of green activities, at the same time narrower and broader compared to various notions used so far in the market, assessing the greenness of financial flows is not obvious. All the more so, in a context characterized by limited availability of relevant data. On the one hand, the economic activities financed via financial instruments labelled as 'green' under other frameworks, might not be fully in line with the Taxonomy definition of green - i.e. not fully Taxonomy-aligned. On the other hand, standard financial products may well be financing green activities, at least to some extent. For general-purpose loans and bonds, as well as for equity financing, it makes sense to measure the greenness of these assets based on the greenness of the business of the company they finance. However, this particular information is at the moment available only for a handful of firms, and will likely remain unavailable for a large number of small and medium enterprises (SMEs), as well as non-EU firms, which have no obligation to disclose on this aspect.

Still, starting in 2024, large financial institutions will need to disclose on the greenness of their overall activities, based on the Taxonomy Regulation.[6] The same regulation imposes that for financial products (investment funds) which claim an environmental objective or environmental characteristics, the Taxonomy alignment of the assets under management will need to be disclosed. These disclosures will be based on the information provided by investee and borrower companies, which have an obligation to disclose if they are EU-based and large enough.[7] Over and above disclosure requirements, financial institutions may want to be able to assess the greenness of their portfolios already now, to start designing credible transition plans, for which they need to know where they start from.

At the same time, it is becoming increasingly relevant for financial institutions to be able to assess how exposed they are to the low-carbon transition. This assessment is important for two reasons. One has to do with mitigating climate transition risks. Regulators have introduced stricter disclosure requirements on the exposure of financial institutions to climate transition risk. In the EU, the European Central Bank has published in November 2020 guidelines that foresee that EU banks integrate climate transition risk in their internal process of risk assessment and management (ECB, 2020). In 2022 the ECB Banking Supervision has carried out a climate risk stress test among large Euro Area banks (ECB, 2022). In the US, as of May 2021 a presidential order requires financial institutions to assess climate risks (US Government, 2021).

However, there is a second reason why a more accurate assessment is needed of financial exposures to the low-carbon transition. This is linked to the mitigation of transition risk via the financing of the transition. While it is true that exposures to particular high-carbon sectors are more risky from a transition perspective, it is also true that precisely these sectors will need to be financed more massively and more urgently in order to facilitate their transition. Companies that are currently active in businesses that are harmful to the environment will need to be financed to help them transition to a sustainable business model. As a matter of fact, if a sector is part of the problem, it needs to be part of the solution.

3. Conceptual framework

The EU Taxonomy provides a definition of green activities that allows to determine the level of greenness of firms and, in turn the greenness of financial portfolios. Applying the EU Taxonomy on a financial portfolio requires to have information on the level of alignment of each firm. In turn, this is based on the level of alignment of each business line of the firm (e.g. consider a firm running multiple plants with different technologies). This data does not yet exist and for some categories of firms, will continue to remain largely unavailable.

Data availability is expected to improve thanks to market pressure and policy action. In the EU, larger firms will soon need to disclose on their Taxonomy-alignment (see Section 2). However, the greenness of a large part of banks' assets, investment funds' AuM and insurers' investments will still need to be assessed in the absence of granular information, as non-EU companies and SMEs have no obligation to calculate and disclose their Taxonomy-alignment. Moreover, with respect to the assessment of climate transition risks, although the extension of the Taxonomy to harmful activities is being discussed, no decision has been taken and it will anyway take some years before technical screening criteria might be available. In the absence of a definition of harmful activities (with the exception of power generation through solid fossil fuels), of course no specific disclosure obligation exists.

On data quality, it is worth stressing that firm-level data on environmental performance are plagued by several measurement issues (see e.g. Papadopoulos (2022) on emissions), and so will data on Taxonomy-alignment and exposure to harmful activities.

Against this background, it is currently not possible to easily assess the greenness of financial portfolios in a way that is comprehensive and transparent. For transition risk, the assessment is even more complicated. The next two sub-sections discuss how one could address this issue by using estimates.

[4] Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088 *(OJ L 198, 22.6.2020, p. 13–43)*.

[5] EU Taxonomy Climate Delegated Act and its Annex 1 and Annex 2 C/2021/2139 *(OJ L 442/1, 9.12.2021)*. The Climate Delegated Act is the basis for this paper. Meanwhile, the so-called 'Complementary Delegated Act' has also become EU law, including some nuclear and natural gas activities in the Taxonomy as green for the climate change mitigation objective.

[6] Delegated Act supplementing Article 8 of the Taxonomy Regulation C/2021/4987 *OJ L 443, 10.12.2021, p. 9–67*.

[7] For SMEs, simplified reporting templates will be developed in the next years. However, disclosure will remain voluntary.

3.1. Coping with lack of information

It should be stressed that the problem financial institutions are facing is two-fold. On the one hand, they need to have information on the greenness or climate-riskiness of each and every counterparts they are exposed to, in order to make investment decisions. On the other hand, to inform their business strategy and the market, they need to have an overall picture of their own greenness and climate-riskiness, which amounts to assessing the greenness and climate-riskiness of their overall *portfolios*. In this subsection, we discuss two possible approaches to treat the portions of a portfolio for which there is no information on greenness or transition risk. For clarity of presentation, we focus on greenness but the same considerations apply to the estimation of climate transition risk.

The first approach to calculate the greenness of a financial portfolio consists in attaching a zero weight to all assets financing firms that do not disclose on their own Taxonomy alignment. This is a conservative approach, which limits the possibility to overestimate greenness, hence ruling out greenwashing practices. It is the approach that EU regulation has taken for some mandatory Key Performance Indicators (KPIs). However, some of the firms that do not disclose information on their Taxonomy alignment could still carry out some green activities. For example, a plumber who installs energy-efficient boilers may not be able or willing to report on the Taxonomy alignment of his activity. This does not make his activity less green. As a second example, non-EU firms may find it more difficult to disclose based on the EU Taxonomy than on their home taxonomies. As for governments, they classify their expenditures in a way that makes it challenging to map them to sectors and activities as structured in the Taxonomy. Still, part of governments' expenditure is towards environmental protection- and will increasingly be so. Hence, attaching a zero weight to all these assets leads to an underestimation of the actual Taxonomy alignment of the portfolio. However, this provides a lower bound.

A second approach is to attempt an estimation of the greenness of those exposures for which there is no data disclosed by the firms on their levels of alignment. On the one hand, this could provide a more accurate estimate than the first approach. On the other hand, any attempt at an estimation of the Taxonomy alignment of the portfolio also carries a risk of overestimation. From a policy perspective, the choice between the two approaches for the computation of mandatory KPIs depends on the balance between the two objectives of fighting greenwashing and increasing the informative content of the disclosures.

3.2. Bottom-up versus top-down estimates of greenness

Estimates of the greenness of a financial portfolio can be carried following either a bottom-up or a top-down approach. These two approaches differ in the granularity of the data (firm-level versus sector-level), the sources and the caveats they come with.

The bottom-up approach consists in the aggregation of firm-level estimates weighted by the value of the investment. In turn, this estimates, may come from (i) estimates by the financial actor or (ii) estimates by a third party, typically a sustainability data provider. To be precise, levels of alignment as disclosed by the firms themselves are also to some extent estimated (e.g. regarding emissions). To keep the presentation simple, we refer to the information provided by the firm as data, while we refer to estimates to indicate computations carried by other parties.

The market has developed several solutions already to provide firm-level estimates of Taxonomy alignment. Among the ones we are aware of, there are S&P Trucost EU Taxonomy Data, the EU Taxonomy Solution by Sustainalytics, the ISS EU Taxonomy Alignment Solution, Moody's EU Taxonomy Alignment Screening, MSCI's EU Taxonomy Methodology, and Bloomberg's SFS Methodology. On top of large market data providers, firm-level Taxonomy data could also be provided by a number of market solutions which have been launched to help firms, in particular SMEs, in assessing their Taxonomy alignment (see Moeslinger et al., 2022). These include Knowshape (Giacomelli, 2021), PlusValue, Worldfavor, ESGgen, and several others.

Virtually all of the players claim to follow the correct approach, i.e. have separate assessment criteria for substantial contribution, do no significant harm and minimum social safeguards (see Section 2). In some cases, data providers distinguish between estimates of the share of the activities of a particular company that is 'aligned', from the share that is 'potentially aligned' or 'likely aligned', reflecting various levels of confidence. In line with the regulation, some provide estimates of the share of revenues, capital expenditure and operational expenditure that is taxonomy aligned. Moreover, estimates are often also based also on confidential information, provided to the market data provider by the company itself, on the basis of their bilateral relationship. This confidential information may be helpful to improve the accuracy of the estimates. Unfortunately, the details of the various approaches are not available, as the actual models mapping firms' information from annual reports and other inputs to the Taxonomy are proprietary. Hence, it is impossible to understand how the data providers come to their detailed assessments of Taxonomy alignment and why they sometimes disagree substantially, as shown in Hoepner and Schneider (2022).

It should also be noticed that this type of assessment of a company's greenness can also be carried out by the financial institution itself, if it has enough resources and in-house expertise. Also in this case, the financial institution can use information that is not public to make an assessment of the greenness of a particular investee company.

Overall, firm-level Taxonomy alignment estimates can help to increase the usability of the Taxonomy and, whenever a counterparty of a financial institution does not disclose on its greenness, can be used to improve the assessment for the portfolio as a whole. However, the following caveats apply.

1. **Data availability and size bias**. Estimates are and will be provided by market data providers only for larger firms, while smaller firms will not be covered. For smaller firms, banks may develop estimates for selected loans in their credit portfolios. However, the estimation of the EU Taxonomy alignment of a business is a highly technical task (it requires e.g. to verify the emissions of an industrial plant) which is beyond the capacity of financial institutions. Digital platforms targeting SMEs are still at an early stage. Hence, firm-level estimates will remain unavailable for large portions of the portfolios.
2. **Disagreement across providers**. As shown in Berg et al. (2022), environmental, social and governance (ESG) ratings tend to vary quite substantially across data providers. One reason is the lack of common definitions for ESG factors. Although Taxonomy alignment relies on a codified definition, there are still large differences in the estimates of alignment across data providers. These could be due for instance to differences in the estimates in CO_2 emissions, in particular if providers use confidential information in their models, as well as to the cited disagreement in ESG ratings, which are one of the ingredients of some Taxonomy assessment solutions. Adding to the confusion, for smaller companies even the degree of disagreement is unknown, as every bank could develop its own estimate of the greenness of a particular borrower but does not need to make it public.
3. **Greenwashing**. Firm-level estimates are prone to substantial greenwashing risk. No matter the provider of the estimates, whether a third party or the financial institution itself, the incentive structure is such that the provider of the estimate will be tempted to make it greener. For data providers, the issue is not much different from the agency problem affecting credit rating agencies. In the case of rating agencies, the rated companies pay fees for those ratings. In the case of data providers, financial institutions pay fees for using the data, and can choose which provider to use. For the same reason why financial institutions may tend to choose the provider of greener estimates, they may also tend to overestimate the greenness of the counterparts for which they develop estimates internally.

The latter is a particularly serious issue, as the proliferation of misleading corporate environmental claims has the potential to jeopardize the entire green finance ecosystem by undermining trust in sustainability claims as a whole, including those made by truly green players. Given the recent exponential growth of sustainability-linked markets,[8] there is more than a suspicion that not all issuers of green or sustainable financial instruments really 'walk the talk'. The suspicion becomes certainty when considering that such a high share of global investments labelled as sustainable is starkly at odds with the global trajectory in terms of sustainability objectives such as climate change mitigation (IPCC-WGII, 2022) and biodiversity preservation (IPBES, 2019). Finally, greenwashing typically materializes into communication and marketing strategies, as well as mis-labelling of financial products; however, as we are entering an era when increased attention is on ESG *data*, unverified greenness estimates can become a powerful means for greenwashing too.[9]

In contrast, top-down estimates are calculated at the level of the portfolio as a whole, and make use of sector-level information, obtained from statistics. One advantage is that it provides estimates also for exposures to non-reporting counterparties. Another advantage is that it can be less exposed to the conflicts of interest and the greenwashing concerns discussed earlier. It should be stressed that a top-down estimate is not meant to make inference on any individual firm in the portfolio. Whenever the objective is to make an assessment on a particular firm or asset, firm-level information should be used. However, whenever the objective is to obtain an estimate of the greenness of a large financial portfolio, a top-down approach can be used, for example to complement a bottom-up approach for the part of the portfolio on which disaggregated estimates are unavailable.

To our knowledge, the only top-down approach available in the scientific literature is the one presented in the next section.

4. Top-down estimation methodology

4.1. Alignment to the EU taxonomy

The EU Taxonomy structure broadly follows the NACE classification, i.e. the statistical classification of economic activities in the European Community. It contains a list of economic activities, and for each activity it indicates the relevant technical screening criteria, i.e. the conditions under which the activity is green, and their rationale. The approach we propose for the estimation of the Taxonomy alignment of financial portfolios is based on the following steps:

1. For each NACE sector explicitly mentioned in the Taxonomy, we estimate a Taxonomy alignment coefficient (TAC), based on publicly available information (e.g. official statistics, reports of the relevant authorities and agencies, sectoral studies and industry reports). In some cases, we develop assumptions or scenarios to derive the TAC. All the sources, the assumptions and the calculations are transparently reported next to each TAC value in the table accompanying this paper.
2. For all the NACE sectors not covered explicitly in the Taxonomy, the TAC is set to zero, as an activity is defined green only if it is included in the Taxonomy.[10]
   Note that there exist about 1000 NACE sectors, as the NACE classification covers the whole economy. However, only a relatively small number are included in the Taxonomy, meaning that technical screening criteria are provided only for activities in those sectors.
3. We estimate the Taxonomy alignment of a portfolio by weighting each asset in the portfolio by the TAC associated with the NACE sector of the investee company or borrower. This firm-level information is generally available for all firms, as they need to declare their main sector of activity upon registration.

In this paper, we present TACs based on Taxonomy technical screening criteria for climate change mitigation. Hence, the TAL estimates the share of the relevant NACE sector which is expected to be Taxonomy-aligned for mitigation (focussing on its substantial contribution, as explained below).

TACs are derived on the basis of information on the economic structure of the EU as a whole. For each economic activity, TACs are thus meant to be estimates for the entire population of EU firms. It follows that TACs provide more accurate estimates of alignment the more the portfolio is representative of the EU firm population. In other words, the TAC represents the best guess for the Taxonomy alignment of a particular firm, based only on its NACE sector of activity. However, the use of TACs is intended for assessing the portfolio as a whole, as individual firms' Taxonomy alignment may be very different from the relevant TAC.

In many cases, although the relevant NACE sector is covered in the Taxonomy, we estimate the associated TAC to zero. This is due to the fact that often, Taxonomy-aligned activities only correspond to a tiny fraction of all the activities belonging to the relevant NACE sector. For example, this is the case of immature technologies, which do not exist at industrial level (e.g. the anaerobic digestion of sewage sludge for biogas production). As another example, the relevant NACE sector may be very broad (e.g. NACE C 20.11 'Manufacture of industrial gases') while the relevant green activity is a niche activity (e.g. the low-carbon manufacture of hydrogen). A TAC equal to zero does not mean, of course, that none of the firms active in a particular NACE sector carries out green activities. However, it indicates that a firm mainly active in that particular NACE sector is associated with a zero *probability* to be carrying out a green activity.

Owing to the practical impossibility to estimate compliance with 'do no significant harm criteria' (DNSH) for activities at the aggregate level, the TACs only refer to the 'substantial contribution' (SC) component. In other words, while we are able to estimate the share of a particular NACE sector making a substantial contribution to the mitigation objective whenever that is material, it is not possible to further estimate which part of this share is furthermore compliant with DNSH criteria. This is because DNSH criteria are in principle 5-dimensional, i.e. there exist a set of criteria for each of the other environmental objectives. Moreover, some of the DNSH criteria do not establish quantitative thresholds, or require the completion of an environmental impact assessment of the activity, or the implementation of mitigation measures. Preliminary evidence based on larger companies indicates that DNSH criteria are particularly stringent when tested against current reality: as of today, it is virtually impossible to find a corporate making a substantial contribution to climate change mitigation and being also in full compliance with all relevant DNSH criteria.[11] At the same time, the

[8] The cumulative green, social, sustainability-linked, and transition labelled debt reached USD3tn at the end Q1 2022 according to Climate Bonds Initiative (https://www.climatebonds.net/resources/reports/sustainable-debt-market-summary-q1-2022). Looking at Europe, the European Securities and Markets Authority (ESMA) calculates that the EU sustainable debt market stood at EUR1.2tn at the end of March 2022, a 50% increase from a year earlier. The assets managed by EU domiciled ESG funds grew by 20% over the same period, to EUR2.1tn. Source: https://www.esma.europa.eu/sites/default/files/library/esma24-442-86_verena_ross_speech_at_icma_agm_9_june_2022_-_greening_the_financial_markets_challenges_and_opportunities_at_the_current_juncture.pdf.

[9] See Gatti et al. (2019) for an overview of available research on greenwashing.

[10] For the sake of precision, an activity is green if it complies with relevant technical screening criteria, even if it belongs to a NACE sector that is not explicitly listed in the Taxonomy. However, these residual cases are irrelevant in a portfolio perspective.

[11] See Sustainable Finance Platform, Report of Data and usability subgroup, 2021, forthcoming.

relevance of some DNSH criteria, in particular those clearly designed for larger corporates, is being questioned for SMEs. In the absence of simplified requirements for SMEs, applying our proposed TACs to an SME portfolio amounts to assuming that an SME in compliance with current relevant regulation is also doing no significant harm to the environment.

It should be noted, that the definition of relevant economic activities in the Taxonomy does not always map one-to-one to the NACE classification. For example, there exist only one NACE sector covering electricity production (D35.11); hence, any firm active in this business will be associated the same NACE code. However, the Taxonomy of course differentiates between renewable energy production and production of electricity via fossil fuels. To address this and similar cases, while there is a unique TAC for each NACE sector, we also provide an activity-specific Taxonomy alignment coefficient (TAC Activity). For example, in the case of electricity production, the TAC for the NACE sector D35.11 corresponds to 37%, i.e. the share of renewables over the whole EU electricity production, while the TAC Activity for any of the renewable energy technologies is 100%, as they are fully Taxonomy-aligned. Whenever only the NACE code of the counterpart is available, the TAC for the relevant NACE sector should be used to weight the asset. However, if enough information is available on the activity of the company, the activity-specific coefficient can be used to obtain a more accurate estimate.

Another issue relates to activities in the Taxonomy that are associated no particular NACE code. This is for example the case for the storage of electricity or hydrogen, which comprises several types of activities classified in several NACE sectors. In this case, the activity cannot be associated a TAC. However, this is not an issue in the context of the top-down approach presented here, which takes NACE sectors as a starting point. In other words, a firm that is active in the storage of electricity or hydrogen will be associated a particular NACE code, and the associated asset will be weighted by the relevant TAC. However, if information is available on that particular counterpart, indicating that it is active in the storage of electricity or hydrogen, then a firm-level estimation can be carried out and a different coefficient can be applied.

Finally, there are some caveats related to the use of firms' NACE codes. The first has to do with the fact that firms may of course be active in more than one NACE sector. If also a secondary NACE code is available for a particular firm, the associated asset can be weighted by using a weighted-average of both relevant TACs. However, most of the times only the NACE code associated with the main activity of a company is available. The second caveat relates to the reliability of firms' NACE codes. Sometimes, these are inaccurate, for example because they may refer to the activity of the company at the time it was founded, while in the meanwhile the business has changed. In other cases, companies operating in real-economy sectors that are potentially relevant for the EU Taxonomy cannot however be traced back to the relevant economic sector, as they appear as financials or others. For example, holding companies are classified under the NACE code Financial and insurance activities (namely K 64.20) or under the NACE code Professional activities etc.(M 70.10). Similarly, financial subsidiaries of non-financial corporations are also classified under K – Financials. Given that the NACE sector K is not covered by the Taxonomy for climate change mitigation, estimates of the greenness of portfolios could increase if a reclassification of firms to relevant NACE sectors based on additional data sources were carried out.

The individual TACs for all relevant NACE sectors and their rationale are described in detail in Appendix A.[12]

[12] An accompanying overview file with all TACs and TECs (see below) and their rationale is available with this paper.

4.2. Exposure to climate transition risk

One essential feature of the EU Taxonomy is that activities that are not green, are not necessarily harmful. In fact, they include the following types of activities: (i) activities that have no significant impact from a climate change mitigation perspective, (ii) activities that do have an impact, but not as positive to be classified green, nor as negative to be defined 'harmful', and (iii) activities which have a negative impact on climate mitigation and, thus are exposed to transition risk, which can materialize depending on changes in policy, technology or preferences.

Hence, while information on the Taxonomy alignment of financial markets and investors' portfolios is key to assess their progress towards green, it does not tell the whole story when it comes to assessing their exposure to climate transition risk.

As a measure of the vulnerability of the European financial system to climate transition risk we take the share of exposures of financial institutions to activities that will be penalized by the low-carbon transition, with the risk of relevant assets becoming stranded, fire-sales involving high-carbon stocks, and loans to high-carbon companies becoming non-performing. However, the quantification of exposures to such activities is also useful to assess the potential for financial institutions to actually finance the low-carbon transition.

Indeed, companies that are active in sectors that will be negatively impacted by the transition, such as fossil-fuels, are also those that will need to be heavily financed to facilitate their own transition. These companies can significantly decrease their exposure to transition risk, even to zero, if they adapt their business model and technology profiles. For instance, electricity generation companies can progressively reduce their reliance on fossil-fuels and turn to renewable energy. A safer way to finance the transition of these counterparts is through green bonds and green loans, i.e. financial instruments foreseeing an obligation for the issuer/borrower to invest the funds into green activities.[13]

We aim to identify portfolio exposures to transition risk by developing activity-level coefficients in a similar spirit to the TACs presented earlier. To this end, we make a step forward compared to the Climate-Policy-Relevant Sectors (CPRS) by Battiston et al. (2017), which have been so far the reference classification in the literature for the assessment of climate transition risk. CPRS overcome the fact that NACE codes associated with activities sharing the same characteristics of transition risk (e.g. revenues driven by fossil-fuels) often belong to different NACE sections, thus preventing a meaningful aggregation. In contrast, CPRS allow to aggregate exposures on the basis of common characteristics with respect to transition risk, such as buildings, transport, utilities, fossil-fuels, etc. However, CPRS may generally be impacted positively or negatively by the low-carbon transition.

To assess exposures to activities that will necessarily be negatively impacted by the low-carbon transition we propose Transition-Exposure Coefficients (TECs), which follow the same TAC logic described above. TECs are also structured based on NACE sectors, and vary from 0, for sectors that do not need to transition, to 100%, for activities that will need to be abandoned going forward. For example, looking at fossil-fuels, we consider all exposures to relevant NACE sectors and subsectors – i.e. those belonging to the 'fossil-fuels' CPRS – as 100% risky from a climate transition viewpoint.

We leverage on the CPRS classification (which does not provide a quantification of transition risk) to assign a TEC to each NACE sector. It is important to clarify that with TECs, we do not aim to quantify the level of losses on individual sectors, as this is conditional to the specific transition scenario (e.g. 1.5C, or 2C) and on assumptions on future levels of negative emissions and model (e.g. IAM REMIND,

[13] In the case of green bonds issued under the EU Green Bond Standard, proceeds need to finance Taxonomy-aligned activities. Green loans are mentioned in the European Commission's 'Strategy for Financing the Transition to a Sustainable Economy'.

MESSAGE, IEA, etc.). Instead, we aim to identify the sectors that are highly exposed to transition risk (i.e. exposed to potential losses) and then to compute the portion of portfolios of investments invested in such activities. The TEC aim to approximate the portion, in value, of activities included in a NACE code, that are exposed to high levels of transition risk. They are assigned according to the following procedure.

1. NACE codes in CPRS fossil-fuel: the TEC equals 1-TAC. Values are mostly 1, as expected. However, some NACE codes in this category include activities, such as the manufacturing of biofuel, that are Taxonomy aligned, hence the TEC is close but not equal to 1.
2. NACE codes in CPRS utility and electricity: the TEC equals the share of fossil fuels in the production, i.e. 39%. The TEC for transmission and distribution of electricity is equal to zero.
3. Taxonomy-relevant NACE codes in CPRS energy-intensive: the TEC is based on relevant Taxonomy DNSH criteria. The value is 0.5, as the DNSH criterion for mitigation defines the least energy-efficient half of the distribution of manufacturing plants as harmful. The TEC for the manufacture of plastics equals 1-TAC, as the Taxonomy criteria for this particular activity follow a different approach compared to other energy-intensive manufacturing activities.
4. Taxonomy-relevant NACE sectors in CPRS transport: we use as a basis for the TEC the transition scenarios elaborated by the international community (e.g. IPCC and IEA), consistent with climate targets of 1.5C and 2C, which foresee in all cases a substantial reduction of the final demand of energy based on fossil-fuel in the transport sector.[14] The TECs in this sector equal 1-TAC, with values very close to 1 as the corresponding TACs reflect the share of electric vehicles. In few cases, NACE codes describing activities that provide auxiliary services to transport inherit the TEC of the corresponding sector.
5. Taxonomy-relevant NACE codes in CPRS buildings: the TEC for real estate activities is based on the relevant Taxonomy DNSH criterion. The value is equal to 0.7 as the regulation defines as significantly harmful the bottom 70% of the building stock.

The individual TECs for all relevant NACE sectors and their rationale are described in detail in Appendix B.

5. Data and results

5.1. Data

The methodology developed in this paper can be applied to any portfolio of holdings, including investment funds and indices. One can also analyse TAC and TEC of "market" strategies, consisting of investing in a particular universe proportionally to available amount. To perform the latter type of analyses, the data is publicly available (commercially). The exact replication of the empirical analysis of holdings presented in this paper requires researchers to have access to supervisory data. However, both equity and bond holdings portfolios can be partially reconstructed using commercially available data. To facilitate the replication of similar future analyses by other researchers, we describe the specific datasets used here but also the data workflow that can be used to implement our methodology on a generic portfolio of holdings.

The analysis is based on 2022Q1 data. The main data sources are two confidential security-by-security databases, namely the Eurosystem's Centralized Securities Database (CSDB) and Securities Holding Statistics (SHS) Database-Sector module. The former contains information on instruments, including prices and issuers, notably including the issuer's NACE sector of activity. The coverage of the CSDB is not limited to securities issued by Euro Area residents, as it also includes securities likely to be held and transacted in by Euro Area residents, as well as other securities denominated in euro. However, we restrict the analysis to securities issued by Euro Area residents as the TAC and TEC are estimated for the EU and could be very different for non European countries. With respect to the information available for each security, the CSDB is also arguably richer than a commercial data provider, as it consolidates micro data from more than 20 national central banks and several commercial sources. The CSDB currently covers more than six million securities. The SHS contains information on the holder side. SHS data cover debt securities, equity instruments and investment fund shares. Securities holdings include aggregated holdings by investors that are grouped into institutional sectors classified according to the ESA2010 methodology, and by country (e.g. households in Spain, banks in Germany...). The SHS covers holdings of investors residing in the Euro Area and several non-Euro Area EU countries (namely Bulgaria, the Czech Republic, Denmark, Hungary, Poland and Romania), and non-resident investors' holdings of Euro Area securities that are deposited with a Euro Area custodian. The SHS database covers around 83% of the total outstanding amount of securities issued by Euro Area residents.[15] In what follows, we focus on debt and equity securities.

In general, one need to match the holdings of financial securities to the characteristics of the issuers of those securities. Debt and equity securities are typically identified by an International Securities Identification Number (ISIN). To identify firms, the international standard is the Legal Entity Identifier (LEI). Unfortunately, commercial data providers use each a different internal code. Information can retrieved using the LEI but in two steps (e.g. in Refinitiv one needs to first retrieve the permID from the LEI). Alternatively, firms can also be identified via the ISIN code of the instrument. However, in the case of bonds the number of different ISIN codes can easily be 10 times larger than the number of firms making certain matching processes cumbersome.

In our study, for the equities we have retrieved the NACE codes by matching the holdings of securities in the SHS to firms NACE codes in the CSDB via the ISIN codes. For the bonds, we have used the LEI to retrieve the NACE codes from Refinitiv. Indeed, in many cases, bonds financing the operations of real-sector firms are issued by a financial subsidiary of the main firm. The issuing firm is typically classified with a NACE code in section K-Finance. For instance, this is the case for most bonds financing car manufacturers. Therefore, taking the NACE code of the issuer face-value leads to underestimate the value of bonds in the real sector and in particular in sectors exposed to transition risk. To address this problem, we have used the LEI to retrieve the NACE codes of the issuer and the NACE code of the parent company (both at 4 digits). When the NACE code of the issuer is in K-Finance but the one of the parent is in a real sector, then we have taken the latter. This corresponds to the assumption that the proceeds of the bond are used to finance the activities of the parent. We performed a set of manual checks to validate this strategy.

In particular, for equities, we start from a sample of about 1 million holdings of stocks from 36 748 distinct issuers corresponding to a total market capitalization of 13.7 tl. Euros. For bonds, we start from 1.6 ml holdings of bonds from 24 368 distinct issuers, corresponding to outstanding bond amount of about 20.4 tl euros. We then aggregate the monetary value of the holdings along the dimensions: ESA2010 sector and country of the holder, ESA2010 sector and country of the issuer, NACE code (4 digits) of the issuer. We then compute the value of Taxonomy Aligned investments by multiplying each amount in the aggregation by the TAC coefficient of its NACE code. Similarly, we proceed for the Transition risk exposure. Our TAC and TEC coefficients are estimated on the basis of statistics for economic activities in the

[14] For instance, internal combustion engines will be banned as of 2025 in the EU.

[15] Source: the ECB Economic Bulletin 2015 issue 2, Article 2 available at https://www.ecb.europa.eu/pub/pdf/other/eb201502_article02.en.pdf.

Table 1
Market's Taxonomy alignment and Transition-exposure by economic sector (NACE main section) for equity shares and bonds. The table does not report sectors where the shares of Taxonomy–eligible, Taxonomy-aligned and Transition-exposed assets are all zero. However, the total amount and the average shares are calculated including investments in all sectors. The figures refer to securities issued by Euro Area resident firms.

NACE code	Sector	Total investment (EUR bn)	Taxonomy eligible (EUR bn)	Taxonomy aligned (EUR bn)	Transition exposure (EUR bn)	Taxonomy eligible (%)	Taxonomy aligned (%)	Transition exposure (%)
A	Agriculture, forestry and fishing	5.6	0.6	0	0	10.9%	0.0%	0.0%
B	Mining and quarrying	123	0	0	110.8	0.0%	0.0%	90.1%
C	Manufacturing	1909.7	765	15.5	438	40.1%	0.8%	22.9%
D	Electricity, gas, steam, airco	515.5	454	206.3	178.6	88.1%	40.0%	34.6%
E	Water supply, sewerage, waste	31.7	30.2	4	0	95.3%	12.6%	0.0%
F	Construction	155.3	155.3	29.1	20.8	100.0%	18.8%	13.4%
G	Trade, repair of motor vehicles	384.3	0	0	6.8	0.0%	0.0%	1.8%
H	Transport and storage	315.3	208.3	5.1	294	66.1%	1.6%	93.3%
J	Information and communication	557.3	476.6	0	0	85.5%	0.0%	0.0%
L	Real estate	237.3	237.3	35.6	166.1	100.00%	15.00%	70.00%
M	Professional, scientific, technical	1706.7	73.6	0	0	4.3%	0.0%	0.0%
N	Support services	101.7	25	0.1	26.3	24.6%	0.1%	25.9%
	…	…	…	…	…	…	…	
	Total	10 635.9	2425.9	295.7	1241.4	22.8%	2.8%	11.7%

EU. We are also interested in holdings of the holders located in the EU. We thus filter the data for holders' and issuers' countries within the European Union (EU27). This results in about 200 th. equity holdings and 800 th. bond holdings, corresponding to about 5.5 tr Euros in both cases. Finally, to provide summary results, we aggregate at the level of holder sectors or at the level of NACE main sections. A summary statistics of the datasets is provided here below.

	Equity full dataset	Bond full dataset	Equity EU27	Bond EU27
n. securities	1′024′199	1′675′683	202′529	805′742
total value (EUR bn)	13′772.81	20′426.83	5′563.30	5′532.30

5.2. Taxonomy alignment and transition-risk exposure by economic sector

In this section we use the TAC methodology to estimate the level of greenness of financial markets based on the EU Taxonomy.[16] Measuring how green financial markets and investors already are, i.e. to what extent they are currently financing Taxonomy-aligned activities, is a first essential step towards designing credible, Paris-aligned transition paths.

Table 1 and Fig. 1 report investors' portfolio composition by economic sector, considering both bond and equity investments together.[17] The table only reports NACE sectors that are relevant for the Taxonomy or the transition discussion, i.e. leaving out all those NACE sectors for which we estimate a zero Taxonomy alignment (as they are not covered by the Taxonomy) and a zero share of high-carbon activities within the sector. These sectors notably include the financial sector, together with education, health, arts and recreation, etc. It should be noticed however that, although not explicitly listed in the Taxonomy as relevant sector, the financial sector is Taxonomy-aligned to the extent it finances Taxonomy-aligned activities.[18] Because of this peculiar treatment of financial activities, which are at the same time excluded from the list of Taxonomy-aligned activities, but can still be Taxonomy-aligned, we assign a TAC of zero to NACE sector K-Financials acknowledging that this is an underestimation (see below). In absolute terms, considering the Taxonomy-relevant economic sectors reported in Table 1 and focussing on the first column, the largest share of investments (almost 2tn) goes to the manufacturing sector, followed by the sector including broader professional, scientific and technical services (1.7 tn) and the information and communication sector (557 bn).

In Columns 2 and 5 we look at the share of assets invested in a particular sector that could possibly be considered as Taxonomy–eligible. A Taxonomy–eligible activity, based on the definition in European law, is an activity that is covered by the Taxonomy. However, a Taxonomy–eligible activity is not necessarily an aligned activity, as it is so only if it meets the relevant technical screening criteria. As such, one could be tempted to use the amount of Taxonomy–eligible activities as a proxy for the potential that a corporate has to improve its Taxonomy alignment. To estimate the amount and share of Taxonomy–eligible activities, we again focus on NACE codes and consider as eligible all NACE sectors mentioned in the law as linked to particular activities. For some sectors this approximation works very well. For example, for the Taxonomy activity 'Manufacture of plastics', we consider the whole NACE sector C20.16 'Manufacture of plastics' as Taxonomy–eligible. For other activities, however, it is unclear where to draw the line between activities that are eligible, but not aligned, and activities that are non-eligible. For example, it is unclear whether a company that is active in waste treatment and disposal (NACE E38.21), but instead of composting bio waste (taxonomy-aligned activity) it disposes it to landfill, would be carrying out an eligible-but-not-aligned activity or a non-eligible activity. Based on this methodology to estimate the share of Taxonomy–eligible activities, the construction and real estate sectors turn out to be 100% Taxonomy–eligible, as they are fully covered by the Taxonomy. Largely eligible sectors are the 'Water supply, sewerage, waste management and remediation' sector (with assets invested in this sector being 95.3% eligible) and the 'Electricity, gas, steam and air conditioning supply' sector (88.1% eligible). These large shares of Taxonomy-eligibility are due to the comparatively large number of activities belonging to these sectors that are included in the Taxonomy. In particular, the Taxonomy lists 12 activities under the section 'Water supply, sewerage, waste management and remediation', which cover almost all of the NACE sectors classified in the same section. The same argument applies to the 'Electricity, gas, steam and air conditioning supply' sector: the Taxonomy includes 25 activities under 'Energy' covering all of the 'Electricity, gas, steam and air conditioning supply' sector except activities related to trade. The large eligibility share of the 'Information and communication' sector, 85.5%, comes as a surprise as only two activities belonging to this sector are included in the Taxonomy. However, a closer look reveals that relevant NACE sectors cover the whole Telecommunications sector, as well as 'Computer programming, consultancy and related activities', and 'Data processing, hosting and related activities', which correspond to essentially all information and communication sectors except publishing and broadcasting. Investments in the 'Transport and storage' sector are 66.1% eligible,

[16] The JRC report (Alessi et al., 2019) documented an earlier version of this analysis using data until December 2018. Some of the coefficients have been revised based on relevant legislation.

[17] Tables 5 and 6 in the Appendix report the allocation by economic sector for bond and equity portfolios separately.

[18] Insurance activities are included for the adaptation objective.

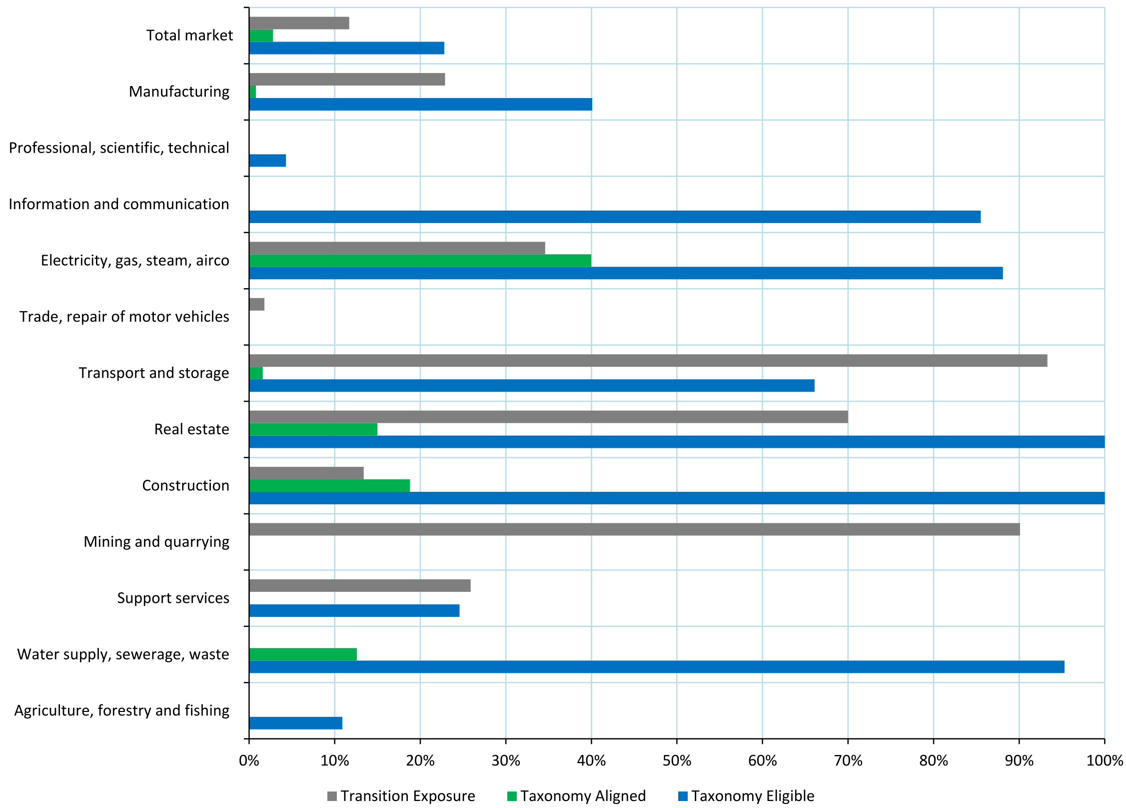

Fig. 1. Taxonomy alignment and Transition-risk exposure by economic sector. Sectors are ordered by size of financial investments.

a relatively large share due to 17 'Transport' activities present in the Taxonomy (though also largely related to other NACE sectors). Finally, the share of eligible investments in the 'Manufacturing' sector is 40.1%, due on the one hand to the relatively large number of manufacturing activities included in the Taxonomy (17), and on the other hand to the large size of the manufacturing sector as a whole. The overall share of eligible assets, also including sectors not shown in the table, is 22.8%.This figure is relevant as it gives an upper bound to any Taxonomy alignment estimate for the market as a whole. It also provides a science-based target for the greening of the financial system: taking the allocation of financial investments *across* sectors as a given, 22.8% is the maximum level of Taxonomy alignment the financial system can reach by reallocating resources *within* sectors.[19]

Next, we report the amount of Taxonomy-aligned assets obtained by using the TAC methodology and their share within the various economic sectors. Columns 3 shows that Taxonomy-aligned amounts are much lower than eligible ones. Indeed, eligibility is only a pre-condition for alignment and, in fact, a TAC of zero is associated to several NACE sectors, even if they are eligible under the Taxonomy (see Appendix). In terms of sector shares (Column 6), the largest discrepancy between eligible and aligned assets relates to information and communication activities (85.5% eligible vs 0 aligned): while a large part of this sector is covered by the Taxonomy, as explained above, relevant technical screening criteria are particularly demanding (e.g. requiring the verification of carefully defined 'expected practices'), hence the share of Taxonomy aligned activities within this sector is very small at this stage. A similar argument applies to the construction (100% vs 18.8%) and real estate (100% vs 15%) sectors: while being fully covered by the Taxonomy, these sectors are characterized by criteria which are satisfied by only a fraction of the buildings/constructions. The transport sector is also characterized by a large gap between the eligibility figure and the alignment figure (66.1% vs 1.6%), as only a very small fraction of this sector currently complies with zero-emission criteria. With respect to the manufacturing sector, the estimated alignment is as low as 0.8%, as the technical screening criteria essentially select only the very top performers in a comparatively small set of manufacturing sub-sectors. In many cases the share of alignment of an entire sector at the level of the NACE main section is zero. The largest share of Taxonomy alignment is associated to the electricity sector (40%), followed by construction (18.8%) and water, sewerage and waste (12.6%). This result is the combination of large eligibility shares for those sectors, coupled with some relatively large TACs, e.g. those based on the share of renewable energy or recycled waste. The overall Taxonomy alignment considering equity and bond investments in all sectors of the economy is estimated at 2.8%. Comparing this figure with the 22.8% eligibility share allows to quantify the transition effort that can at most be expected from the financial system, i.e. around 20% of financing being diverted to green activities. This number should be regularly updated to monitor progress at the level of the system as a whole.

Finally, Columns 4 and 7 report the amount and share of transition-risk exposures, i.e. high-carbon exposures estimated via the TECs. The highest transition-risk exposure share, 93.3%, is associated to the transport sector. This figure is quite concerning, as it indicates that for every euro that is invested in the transport sector today, more than 90 cents are at risk of becoming a loss. This is due to the currently overwhelming share of internal combustion engine vehicles and large share of non-electrified railways. The transport sector is followed by the 'Mining and quarrying' sector with a 90.1% transition-risk exposure, as a large part of this sector is related to fossil-fuel extraction, which has a TEC of 1. While, in general, transition-risk exposure estimates do not necessarily mean that a loss will occur – as companies and borrowers can make their business more sustainable – in the case of the mining and quarrying sector it is much more likely that the risk will actually

[19] Of course, this figure will increase with the inclusion of more green activities in the Taxonomy.

Table 2
Investors' portfolios: Taxonomy alignment and Transition-risk exposure. The figures refer to the sum of equity and bond portfolios, covering securities issued by Euro Area resident firms.

Holder sector	Total investment (EUR bn)	Taxonomy eligible (EUR bn)	Taxonomy aligned (EUR bn)	Transition exposure (EUR bn)	Taxonomy eligible (%)	Taxonomy aligned (%)	Transition exposure (%)
Investment funds (Non-MMF)	2856.3	815.1	91.5	344	28.5%	3.2%	12.0%
Banks	2020.1	157	16.8	100.2	7.8%	0.8%	5.0%
Non-financial corp.	1424.2	300.4	41.7	164.3	21.1%	2.9%	11.5%
Insurance corp.	1261.4	346.5	60.2	190.7	27.5%	4.8%	15.1%
Households	936.9	250.6	24	115.1	26.8%	2.6%	12.3%
Other financial corp.	825.5	158.2	11.8	128.5	19.2%	1.4%	15.6%
Other households and non-profit	317.3	84.2	2.9	11.1	26.5%	0.9%	3.5%
Pension funds	2 29.5	62.6	10.3	32.8	27.3%	4.5%	14.3%
Central gov.	157.2	60.4	4.7	55.9	38.4%	3.0%	35.6%
Other General Gov.	122	54.7	12.9	26.7	44.9%	10.6%	21.9%
Non-EA other investors	100.7	29	2.9	9.5	28.8%	2.9%	9.4%
Non-financial investors	75	39.1	8	25.9	52.2%	10.6%	34.5%
Non-profit institutions	61.4	14.4	1.7	10.9	23.5%	2.7%	17.8%
Money market funds (MMF)	60.8	14.8	1.3	9.5	24.3%	2.2%	15.7%
Financial vehicle corp.	60.4	12.5	1.2	4.4	20.6%	2.0%	7.3%
Social security funds	58.7	18.2	2.2	7.3	31.0%	3.8%	12.5%
State gov.	34.4	2.8	0.2	2.4	8.2%	0.5%	7.0%
Local gov.	29.6	4.9	1.5	2.1	16.4%	5.0%	7.0%
Non-EA central banks & gov.	4.1	0.3	0	0.3	8.1%	0.4%	7.3%
Unallocated	0.1	0	0	0	38.1%	5.9%	19.7%
Total	10 635.6	2425.7	295.8	1241.6	22.8%	2.8%	11.7%

materialize, as diversification is in principle more difficult for these firms whose assets are essentially fossil fuel reserves. The transition-risk exposure of the real estate sector is estimated at 70%, due to the roughly 70% of the building stock which is currently energy inefficient. The worst performing buildings may need to undergo a renovation in order to reduce their energy consumption and emissions in view of the gradual introduction of minimum energy performance standards. The exposure of the electricity sector is estimated at 34.6% and linked to fossil fuel usage. Finally, the manufacturing sector is 22.9% exposed, a relatively low share due to the fact that although relevant TECs are sometimes quite large, affected manufacturing sectors are only few out of many. The other sectors have a low one-digit or zero estimated exposure. The overall exposure to transition risk for the market as a whole is estimated at 11.7%. This figure, although non-negligible, is not breathtaking, especially considering that not all of these exposures are bound to become losses. However, what also matters is the concentration of this risk among investors, as discussed in the next section.

5.3. *Taxonomy alignment and transition-risk exposure by investor*

In this section we analyse the composition of Euro Area investors' portfolios in terms of Taxonomy alignment and exposure to transition risk. Table 2 and Fig. 2 list holder sectors starting with the largest institutional investors. Column 1 in the table shows the size of the overall investment portfolio, including both equities and bonds.[20] The largest investor sector is of course investment funds, holding almost 3 tn securities issued by Euro Area resident firms, followed by banks with about 2 tn.

Columns 2 and 5 look at Taxonomy–eligible assets, in billions and as portfolio share, respectively. In absolute terms, investment funds hold the largest amount of Taxonomy–eligible assets (more than 800 bn) as they are by far the largest investors. However, non-financial corporations, insurers and households all hold more Taxonomy–eligible assets (around 300 bn, 350 bn, and 250 bn, respectively) than banks (around 150 bn). Looking at the share of Taxonomy–eligible assets and focussing on the largest investors, Column 5 shows a large difference between investment funds, non-financial corporates, insurers and households (all above 20%) on the one hand, and banks (7.8%) on the other. A possible explanation for the low share of Taxonomy–eligible assets on banks' balance sheet as compared to other investors is their relatively large exposure to the financial sector. Indeed, as shown in Table 9 in the Appendix for bond holdings, once securities issued by financial firms are excluded, the figures for the banking sector become comparable to those for the other investor classes (e.g., 36.8% for Transition exposure).

Turning to the Taxonomy-alignment share (Column 6), the 'Other General Government' and 'Non-financial investors' sectors stands out with 10.6%. For the 'Other General Government' sector, this relatively large overall Taxonomy-alignment is due to the exceptionally large alignment of its bond holdings (see Tables 8 and 9 in the Appendix) and equity stakes (see Table 7 in the Appendix), arguably in companies active in sectors associated with comparatively large TACs, such as transport. Non-financial corporates (as investors) are associated a 2.9% Taxonomy alignment; however, it should be stressed that what matters for the Taxonomy alignment of a non-financial company is the greenness of its business, not the greenness of its investments. Looking at financial institutions, banks are associated the lowest Taxonomy alignment share (0.8%), while the others range between 2% (financial vehicles) and 4.8% (insurers).In analogy with the result on Taxonomy-eligibility, the comparatively low Taxonomy alignment of banks is likely due to their comparatively larger exposures to the financial sector.

Finally, Columns 4 and 7 show the amount and share of riskier exposures from a transition perspective, based on the TECs. For all investor sectors, these are larger than Taxonomy-aligned financial assets. Non-financial investors and Central Government are the most exposed categories of investors (both around 35%). This result shows that should a large-scale materialization of transition risk take place, there could be severe consequences on the fiscal front owing to the particularly large exposure of central governments via their assets. This finding complements the available literature on the exposure of sovereigns to transition risk via their liabilities, i.e. through yield increases (Battiston & Monasterolo, 2019; Zenios, 2022). Insurers', other financial corporates', other general government's, non-profit institutions' and money-market funds' exposures to transition risk are all above 15%. Looking at households, the relatively high figure (12.3%) indicates that, while retail investors are increasingly buying socially

[20] Disaggregated results for equities and bonds are available in Appendix. In the Appendix we also provide a table for bond holdings where we have performed the calculations by excluding all bonds issued by firms belonging to NACE sector K, i.e. Finance.

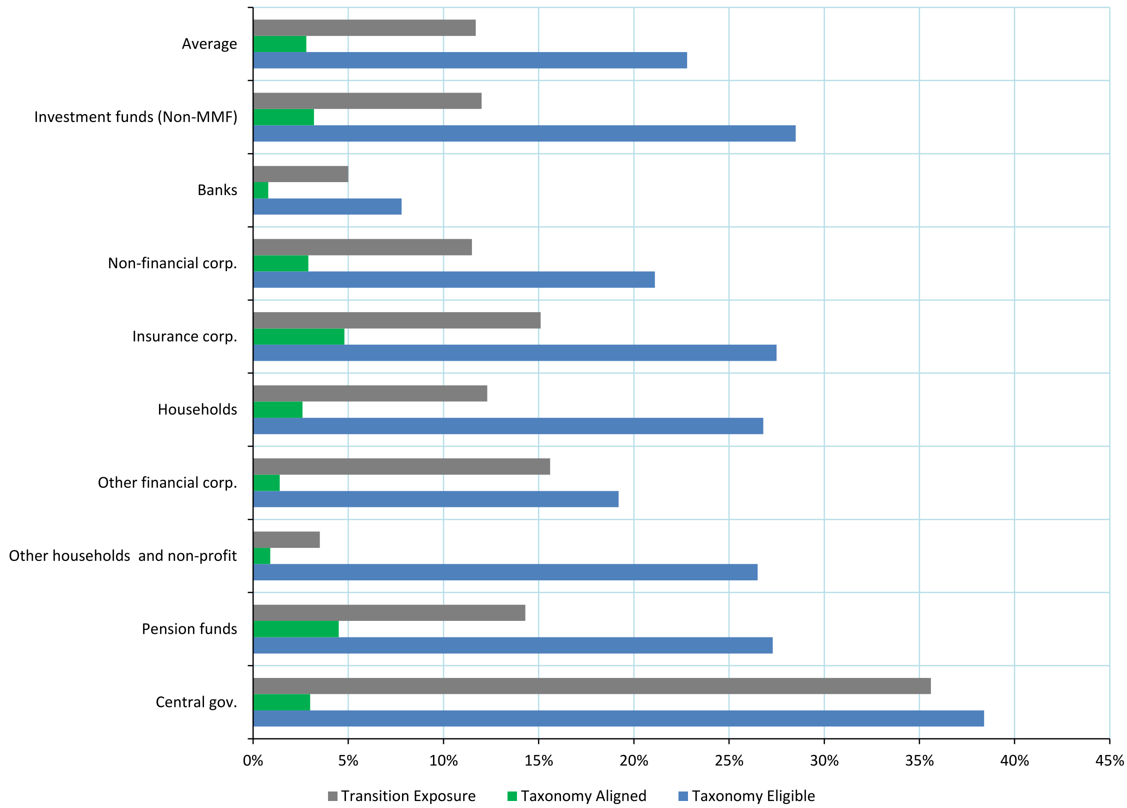

Fig. 2. Taxonomy alignment and Transition-risk exposure by investor class.

responsible products (see Alemanni, 2022 and references therein), they might not be as careful when screening the remaining part of their investments, with almost 1 in 10 euros being actually invested in harmful activities. In some cases, such as non-financial investors, a high transition-risk exposure might be due to stakes in sectors that are at the same time comparatively greener and particularly exposed to transition risks. This is the case for example of electricity production, which is associated a TAC of 0.35 but also a TEC of 0.39. However, in some other cases such as other financial corporations, a comparatively high exposure to transition risk is not associated with a particularly elevated Taxonomy alignment, highlighting a substantial exposure to the fossil fuel sector. This result is essentially due to their equity holdings and is consistent with Alessi, Battiston et al. (2021), who show that less regulated financial institutions increased their holdings of high-carbon companies after the Paris Agreement.

Notice that, for the same sector, transition-risk exposures may differ when focusing only on equity shares or bonds (see Tables 7 and 8 in the Appendix). In particular, equity portfolios are slightly more exposed to transition risk than bond portfolios, indicating that particularly risky activities such as those related to fossil-fuels may tend to be financed primarily via the purchase of stocks than bonds. In the case of banks, the risk differential between bond (or overall security) exposures and equity exposures is particularly striking, as estimated exposures to transition risk amount to around 20% of equity portfolios (as opposed to 5% overall). This is particularly concerning, as stocks would be particularly vulnerable in case of a fire sale of high-carbon assets.[21]

6. Conclusions and further research

In this paper we develop a simple methodology that financial institutions can use to assess both the greenness of their portfolios, as well as their exposure to climate transition risk. We illustrate the methodology on confidential data on Euro Area investors' holdings. This methodology is based on standardized coefficients covering all sectors of the economy, based on the NACE classification, which often is the only readily available information that an investor has on an investee company or borrower. For this reason, this methodology applies in particular to exposures to SMEs, which would be impossible to assess otherwise. We make the sector-specific coefficients available as an open-access table for risk monitoring and management for both investors and supervisors.

Our methodology highlights the interplay between greenness and transition risk in financial portfolios. As we show, investors that have comparatively larger amounts invested in green assets often also have large exposures to transition risk. The question is then how can financial actors become greener by not increasing and even reducing their exposure to transition risk, when in fact most of the greenest sectors are also those with the highest exposure to transition risk, and companies often carry out both green and harmful activities. There are essentially two main recommendations.

The first one is to invest by means of green bonds and loans, i.e. instruments that condition the use proceeds to green activities. In particular, green bonds issues under the EU Green Bond Standard are 100% Taxonomy aligned assets. Notice that the transition risk associated to those green instruments is the transition risk associated to the counterparty, which could still be high. Nonetheless, the use of green instruments is key to ensure that high-carbon counterparties proceed in their transition and hence decrease their exposure to transition risk, leading to an overall risk reduction also from a portfolio perspective.

The second recommendation is to look at the Taxonomy alignment of investee companies' capital expenditure (CapEx), together with the Taxonomy alignment of their revenues. Indeed, while the latter takes a snapshot of where the company stands today, CapEx provides information on the direction of travel. Firms with a greener CapEx today will have a greener turnover tomorrow, which means that even in

[21] On the potential impact of a fire sale of high-carbon assets see Alessi et al. (2022).

the absence of portfolio reallocation the portfolio overall will be also greener.

In what follows, we discuss the main limitations of the methodology proposed in this paper and some extensions.

First, all the coefficients are estimated for each activity as an aggregate, on the basis of public information and, in some cases, assumptions, that are reported transparently in the Appendix and in the annex table. Carrying out these estimates takes substantial work, across very different areas of technology and regulation. Our aim here is to demonstrate that it is feasible and useful to carry out such an exercise. It is entirely possible that these estimates could be refined based on additional information by experts in the various specific fields. Also, these coefficients should be subject to a regular update to reflect the greening of relevant economic sectors, as well as the progressive tightening of some Taxonomy technical screening criteria. Moreover, further work could build on this approach to develop coefficients covering the other five environmental objectives of the EU Taxonomy, both in terms of alignment and risk.

Second, these coefficients are intended to provide a reference value for large and unbiased portfolios. In the case of a portfolio that has a bias towards firms that, for instance, outperform in terms of greenness, this bias cannot be not captured by the coefficients as they are. Moreover, considering that greener firms have a higher incentive to disclose compared to other firms, the part of the portfolio on which the investor has no information, and for which our TAC tool is most useful, would arguably carry a lower Taxonomy alignment. Still, given the current extent of voluntary disclosures (virtually non existing) and the size of most TACs (close to zero), this will not be a material issue for some time to come. Future research could deal with the development of correction coefficients for TACs and TECs to take these dynamics into account once they become significant.

Third, the coefficients we provide in this paper are calibrated on the EU as a whole. For some sectors, such as electricity generation, there are large differences across Member States and more accurate estimates could be obtained by developing coefficients at the country-level. Moreover, in order to allow for a more comprehensive assessment of the level of greenness and transition risk, one could develop coefficients for non-EU countries, to be able to asses exposures to companies that are not subject to EU regulation, including on the disclosure of their Taxonomy alignment.

Fourth, the TAC and TEC currently associated to the financial sector are set to zero in this work. In order to estimate them more accurately, it would be necessary to unfold the holdings of this sector. In principle, it would be possible to estimate their value, recursively, based on the analysis carried out in the last part of this paper. Moreover, in general we do not develop coefficients for NACE sectors at higher levels of aggregation, as the larger the sector, the smaller and more difficult to estimate the coefficient. However, it would be possible to estimate the share of Taxonomy alignment and Transition exposure at any level of aggregation (e.g. NACE 2-digit) by aggregating the relevant financial amounts resulting from our empirical exercise.

Finally, the coefficients presented in this work only cover securities issued by non-financial corporations. However, sovereign bonds constitute a large part of financial institutions' portfolios, hence a methodology to assess their greenness and level of transition risk would be extremely useful. As a starting point for sovereign TACs one could use official statistics on public expenditure for environmental protection, which would yield a greenness of around 1% on average for the EU, although this could only be a rough proxy given the rather loose link with the Taxonomy. With respect to banks' exposures to central banks, one could weight them by using the coefficients we estimate in this paper for the market as a whole (2.8% Taxonomy alignment and 11.7% exposure to transition risk), given that central banks follow a market neutrality principle.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Taxonomy alignment coefficients: values and rationale

A.1. Forestry

Forestry activities included in the Taxonomy are the following: Afforestation, Rehabilitation and Restoration of forests (including reforestation and natural forest regeneration after an extreme event), Forest management, and Conservation forestry. All of these activities belong to NACE sector A2 'Forestry and logging'. Given the breadth of this NACE sector, which notably includes the whole logging industry, and the SC requirements for the above activities to be considered green (e.g. the existence of a forest management plan of five or ten years), Taxonomy-aligned activities are likely to be a very small fraction of sector A2. Hence, we propose a TAC of zero for this sector.

A separate set of activities, somehow related to forestry but distinct, consists of environmental protection and restoration activities, which include the restoration of wetlands. This activity is associated no particular NACE code.

A.2. Manufacturing

Two types of manufacturing activities are included in the Taxonomy. A first group of activities comprises the manufacture of renewable energy technologies, equipment for the production and use of hydrogen, low-carbon technologies for transport, batteries, energy efficiency equipment for buildings, an other low-carbon technologies. Most of these activities are linked to multiple NACE sectors. For example, the manufacture of renewable energy technologies involves the manufacture of fabricated metal products (NACE C25), electrical equipment (C27) and of machinery and equipment (NACE C28). These NACE sectors, or some specific sub-sectors, are also linked to most of the other productions mentioned in this group of activities. In general, we associate a TAC equal to zero to the NACE sectors associated with this particular group of activities, given the breadth of these manufacturing NACE sectors (e.g. C22 'Manufacture of rubber and plastic') against the specificity of relevant green activities, such as the manufacturing of low-carbon technologies.

Two notable exceptions in the group of activities mentioned above are the following. One is the manufacture of batteries, which is associated with two relatively narrow NACE sectors, namely C27.2 'Manufacture of batteries and accumulators' and E38.32 'Recovery of sorted materials'. We associate a TAC equal to 1 to NACE C27.2 as well as to NACE E38.32, as the recovery of sorted materials is also relevant for the activity of 'Material recovery from non-hazardous waste' under 'Water supply, sewerage, waste management and remediation'. The second exception are two NACE sectors associated with the 'Manufacture of low carbon technologies for transport', namely NACE C29.1 'Manufacture of motor vehicles' and NACE C30.2 'Manufacture of railway locomotives and rolling stock'. The TAC associated with the former is 2% and corresponds to the share of electric vehicles (excluding hybrid plug-in vehicles, which are not compliant with the SC criteria) newly registered in the EU (2019 data, source European Environment Agency). The TAC associated with the latter corresponds to the share of electrified railway lines in the EU, i.e. 56% (source Eurostat).

The second group of activities comprises the manufacture of cement, aluminium, iron, steel, hydrogen, carbon black, soda ash, chlorine, organic basic chemicals, anhydrous ammonia, nitric acid, and plastics. For most of these activities, the SC threshold in terms of GHG emissions

Table 3
Overview of TAC rationales by activity category with illustrative examples of relevant NACE sectors.

Macrosector	Activities	TAC rationale	Example NACE sector	TAC
Forestry	Forestry	Negligible alignment at this stage	Forestry (A.02)	0
Manufacturing	Low-carbon technologies	Negligible alignment at this stage	Manufacture of electrical equipment (C.25)	0
	Batteries	NACE sector virtually fully aligned	Manufacture of batteries and accumulators (C27.2)	1
	Motor vehicles and trains	Share of electric vehicles/railways	Manufacture of railway locomotives […] (C30.2)	0.56
	High-carbon productions	Top-performers in the NACE sector	Manufacture of cement (C.23.51)	0.05
	Plastic	Share of recycled plastic	Manufacture of plastics in primary forms (C.20.16)	0.07
Energy	Electricity production	Share of renewables	Production of electricity (D35.11)	0.35
	Transmission, distribution and storage	NACE sector virtually fully aligned	Distribution of electricity (D.35.13)	1
	Biogas, biofuels, low-carbon gases	Negligible alignment at this stage	Distribution of gaseous fuels (D35.22)	0
	Heating and cooling	Share of renewables/heatpumps	Steam and air conditioning supply (D35.30)	0.21
Water, sewerage, waste	Water collection, treatment and supply	Negligible alignment at this stage	Sewerage (E37)	0
	Waste	Share of recycled waste	Collection of non-hazardous waste (E38.11)	0.38
	CO2 transport and storage	Negligible alignment at this stage	Transport via pipeline (H49.50)	0
Transport	Land transport	Share of electric vehicles/railways	Urban and suburban passenger land transport (H49.31)	0.02
	Water transport	Negligible alignment at this stage	Inland freight water transport (H.50.40)	0
	Transport infrastructure	Negligible alignment at this stage	Engineering activities […] (M.71.12)	0
Construction and real estate	New buildings and renovation	Model-based	Construction of buildings (F41)	0.4
	Equipment and technologies	Negligible alignment at this stage	Repair of household appliances […] (S.95.22)	0
	Real estate	Top-performing buildings	Real estate activities (L68)	0.15
Information and communication	Information and communication	Negligible alignment at this stage	Telecommunications (J.61)	0
Professional scientific and technical activities	Research, development and innovation	Negligible alignment at this stage	Research and experimental development on natural sciences and engineering (M.72.1)	0

Table 4
Overview of TEC rationales by activity category with illustrative examples of relevant NACE sectors.

Macrosector	Activities	TAC rationale	Example NACE sector	TEC
Fossil fuels	Extraction, manufacturing and sale	NACE sector virtually fully exposed	Mining of coal and lignite (B.05)	1
Manufacturing	Motor vehicles and trains	Share of fossil-fuel-propelled transport	Manufacture of railway locomotives […] (C30.2)	0.44
	High-carbon productions	Worst performers in the NACE sector	Manufacture of cement (C.23.51)	0.5
	Plastic	Share of recycled plastic	Manufacture of plastics in primary forms (C.20.16)	0.93
Energy	Electricity production	Share of fossil fuels	Production of electricity (D35.11)	0.39
	Heating and cooling	Share of fossil fuels	Steam and air conditioning supply (D35.30)	0.39
Transport	Land transport	Share of fossil-fuel-propelled transport	Taxi operation (H.49.32)	0.997
	Water transport	Share of fossil-fuel-propelled transport	Inland passenger water transport (H.50.30)	1
	Air transport	Share of fossil-fuel-propelled transport	Service activities incidental to air transportation (H.52.23)	1
Real estate	Real estate	Worst-performing buildings	Real estate activities (L68)	0.7

Table 5
Equity market's Taxonomy alignment and Transition-exposure by economic sector. The table does not report sectors where the shares of Taxonomy–eligible, Taxonomy-aligned and Transition-exposed assets are all zero. However, the total amount and the average shares are calculated including investments in all sectors. The figures refer to securities issued by Euro Area resident firms.

NACE code	Sector	Total investments (EUR bn)	Taxonomy eligible (EUR bn)	Taxonomy aligned (EUR bn)	Transition exposure (EUR bn)	Taxonomy eligible (%)	Taxonomy aligned (%)	Transition exposure (%)
A	Agriculture	2.3	0	0	0	0.3%	0.0%	0.0%
B	Mining and quarrying	98.1	0	0	92.3	0.0%	0.0%	94.2%
C	Manufacturing	1370	503.7	9.9	259.2	36.8%	0.7%	18.9%
D	Electricity	291.8	238.1	86.6	106	81.6%	29.7%	36.3%
E	Water supply	11.4	10.6	1.3	0	93.3%	11.4%	0.0%
F	Construction	111.7	111.7	21.2	1.4	100.0%	19.0%	1.3%
G	Trade	328.1	0	0	4	0.0%	0.0%	1.2%
H	Transport	181.9	109.4	0.6	170.6	60.2%	0.3%	93.8%
J	Information and communication	398	348.5	0	0	87.6%	0.0%	0.0%
L	Real estate	98.5	98.5	14.8	69	100.0%	15.0%	70.0%
M	Professional, scientific and technical	1684.2	68	0	0	4.0%	0.0%	0.0%
N	Support services	33.5	0	0	0.7	0.1%	0.0%	2.0%
…	…	…	…	…	…	…	…	…
	Total	5563.3	1488.5	134.4	703.2	26.8%	2.4%	12.6%

Table 6
Bond market's Taxonomy alignment and Transition-exposure by economic sector. The table does not report sectors where the shares of Taxonomy–eligible, taxonomy-aligned and Transition-exposed assets are all zero. However, the total amount and the average shares are calculated including investments in all sectors. The figures refer to securities issued by Euro Area resident firms.

NACE section	Sector	Total investment (EUR bn)	Taxonomy eligible (EUR bn)	Taxonomy aligned (EUR bn)	Transition exposure (EUR bn)	Taxonomy eligible (%)	Taxonomy aligned (%)	Transition exposure (%)
A	Agriculture	0.8	0.3	0.0	0.0	37.7%	0.0%	0.0%
B	Mining and quarrying	91.3	0.0	0.0	77.0	0.0%	0.0%	84.4%
C	Manufacturing	495.6	181.9	3.5	91.1	36.7%	0.7%	18.4%
D	Electricity	171.7	137.7	64.0	55.9	80.2%	37.3%	32.5%
E	Water supply	18.2	17.1	3.7	0.0	94.3%	20.3%	0.0%
F	Construction	46.9	46.9	14.8	3.2	100.0%	31.5%	6.8%
G	Trade	70.1	0.0	0.1	6.7	0.0%	0.1%	9.5%
H	Transport	213.9	154.5	4.8	180.0	72.3%	2.2%	84.2%
J	Information and communication	308.3	255.3	0.0	0.0	82.8%	0.0%	0.0%
L	Real estate	96.4	96.4	14.5	67.5	100.0%	15.0%	70.0%
M	Professional activities	439.9	14.3	0.0	0.0	3.3%	0.0%	0.0%
N	Support services	33.0	1.1	0.0	5.6	3.4%	0.0%	16.9%
…	…	…	…	…	…	…	…	…
	Total	14 884.8	905.6	105.3	486.9	6.1%	0.7%	3.3%

Table 7
Investors' portfolios: Taxonomy alignment and Transition exposure. The figures refer to the equity portfolio and to securities issued by Euro Area resident firms.

Holder sector	Total investment (EUR bn)	Taxonomy eligible (EUR bn)	Taxonomy aligned (EUR bn)	Transition exposure (EUR bn)	Taxonomy eligible (%)	Taxonomy aligned (%)	Transition exposure (%)
Investment funds (Non-MMF)	1496.3	410.5	24.5	118.4	27.4%	1.6%	7.9%
Non-financial corp.	1329.5	286.2	39.8	155.8	21.5%	3.0%	11.7%
Households	735	224.8	20	101.6	30.6%	2.7%	13.8%
Other financial corp.	710.1	150.1	10.7	123	21.1%	1.5%	17.3%
Other households and non-profit	291.4	83.2	2.8	10.4	28.6%	1.0%	3.6%
Insurance corp.	242.4	63.2	5.5	22	26.1%	2.3%	9.1%
Banks	219.1	66.4	3.3	43.2	30.3%	1.5%	19.7%
Central gov.	120.2	56.8	4.1	53.7	47.3%	3.4%	44.7%
Other General Gov.	97.8	41.4	9.1	20.1	42.3%	9.3%	20.6%
Non-financial investors	72.5	38	7.9	24.9	52.5%	10.9%	34.3%
Pension funds	69.3	20.3	1.9	9.2	29.3%	2.7%	13.2%
Non-EA other investors	63.4	17.4	1	3.4	27.4%	1.6%	5.4%
Non-profit institutions	37.3	9.5	1	7.9	25.6%	2.6%	21.3%
Social security funds	33.6	13.3	1.3	4.9	39.5%	3.8%	14.5%
State gov.	21.9	2.5	0.1	2.1	11.2%	0.5%	9.8%
Local gov.	17.7	4.1	1.4	1.9	23.1%	7.9%	10.7%
Financial vehicle corp.	4.1	0.8	0	0.5	20.1%	0.9%	12.3%
Money market funds (MMF)	1.5	0.2	0	0.1	12.4%	0.3%	6.9%
Unallocated	0.1	0	0	0	36.9%	5.4%	18.9%
Non-EA central banks & gov.	0	0	0	0	100.0%	0.0%	0.0%
Total	5563.2	1488.7	134.4	703.1	26.8%	2.4%	12.6%

corresponds to the average value of the 10% most efficient installations. Assuming installations are uniformly distributed, 5% would then meet the requirements. Hence, we propose a TAC of 5% for the NACE sectors associated with these activities.

The SC thresholds for the manufacture of plastic and hydrogen are not set based on the rationale described above, hence the associated TACs need to be derived differently. For the former, the TAC is equal to 7%, corresponding to the share of recycled plastics demand in EU (6%) plus the share of bioplastics (1%). As for the latter, the manufacturing of hydrogen belongs to NACE C20.11 'Manufacture of industrial gases': given the extremely small share of hydrogen over the whole of industrial gases, the TAC associated with this NACE sector is zero.

A.3. Energy

The first group of energy-related activities concerns electricity production. The relevant NACE codes for these activities are D35.11 'Production of electricity' and F42.22 'Construction of utility projects for electricity and telecommunications'. NACE D35.11 covers the production of electricity from renewable sources, as well as from fossil-fuels and nuclear. The TAC for this sector is 35% and corresponds to the share of the production of electricity and derived heat from renewable sources in the EU (2019 data, source Eurostat). The TAC for NACE F42.22 is 26% and is obtained as the share of gross fixed capital formation (GFCF) in the electricity sector over the total GFCF in the electricity and communication sectors taken together (74%) multiplied

Table 8
Investors' portfolios: Taxonomy alignment and Transition exposure. The figures refer to the bond portfolio and to securities issued by Euro Area resident firms.

Holder sector	Total investment (EUR bn)	Taxonomy eligible (EUR bn)	Taxonomy aligned (EUR bn)	Transition exposure (EUR bn)	Taxonomy eligible (%)	Taxonomy aligned (%)	Transition exposure (%)
Banks	1801	90.5	13.5	57	5.0%	0.8%	3.2%
Investment funds (Non-MMF)	1360	404.6	66.9	225.5	29.8%	4.9%	16.6%
Insurance corp.	1019	283.3	54.7	168.6	27.8%	5.4%	16.6%
Households	201.9	25.9	4	13.4	12.8%	2.0%	6.7%
Pension funds	160.3	42.3	8.5	23.6	26.4%	5.3%	14.8%
Other financial corp.	115.4	8.1	1	5.4	7.0%	0.9%	4.7%
Non-financial corp.	94.8	14.2	1.9	8.5	15.0%	2.1%	9.0%
Money market funds (MMF)	59.3	14.6	1.3	9.4	24.6%	2.2%	15.9%
Financial vehicle corp.	56.3	11.6	1.2	3.9	20.7%	2.1%	6.9%
Non-EA other investors	37.3	11.6	1.9	6.1	31.2%	5.2%	16.2%
Central gov.	37	3.6	0.6	2.2	9.8%	1.7%	6.0%
Other households and non-profit	26	1	0.1	0.7	3.7%	0.5%	2.6%
Social security funds	25.1	4.9	0.9	2.5	19.7%	3.6%	9.8%
Other General Gov.	24.2	13.4	3.8	6.5	55.2%	15.7%	27.0%
Non-profit institutions	24.1	4.9	0.7	3	20.3%	2.9%	12.3%
State gov.	12.5	0.4	0	0.3	3.0%	0.4%	2.1%
Local gov.	11.9	0.8	0 .1	0.2	6.5%	0.8%	1.5%
Non-EA central banks & gov.	4.1	0.3	0	0.3	8.1%	0.4%	7.3%
Non-financial investors	2.5	1.1	0.1	1	44.9%	3.5%	39.3%
Unallocated	0	0	0	0	40.3%	6.8%	21.0%
Total	5072.5	937.1	161.4	538.1	18.5%	3.2%	10.6%

Table 9
Investors' portfolios: Taxonomy alignment and Transition exposure. The figures refer to the bond portfolio and to securities issued by Euro Area resident firms, excluding all bonds issued by firms belonging to NACE sector K 'Finance'.

Holder sector	Total investment (EUR bn)	Taxonomy eligible (EUR bn)	Taxonomy aligned (EUR bn)	Transition exposure (EUR bn)	Taxonomy eligible (%)	Taxonomy aligned (%)	Transition exposure (%)
Investment funds (Non-MMF)	658.4	404.6	66.9	225.5	61.5%	10.2%	34.3%
Insurance corp.	428.1	283.3	54.7	168.6	66.2%	12.8%	39.4%
Banks	154.9	90.5	13.5	57	58.5%	8.7%	36.8%
Pension funds	67.8	42.3	8.5	23.6	62.5%	12.5%	34.9%
Households	43.5	25.9	4	13.4	59.4%	9.2%	30.9%
Non-financial corp.	25.7	14.2	1.9	8.5	55.1%	7.6%	33.1%
Financial vehicle corp.	24.9	11.6	1.2	3.9	46.8%	4.7%	15.6%
Money market funds (MMF)	19.6	14.6	1.3	9.4	74.6%	6.7%	48.2%
Other financial corp.	17.3	8.1	1	5.4	46.7%	6.0%	31.5%
Non-EA other investors	17	11.6	1.9	6.1	68.5%	11.5%	35.6%
Other General Gov.	16.9	13.4	3.8	6.5	79.0%	22.5%	38.6%
Non-profit institutions	7.8	4.9	0.7	3	62.4%	9.0%	37.9%
Social security funds	7.2	4.9	0.9	2.5	68.1%	12.6%	33.9%
Central gov.	5	3.6	0.6	2.2	71.9%	12.3%	43.8%
Other households and non-profit	1.9	1	0.1	0.7	51.0%	6.2%	35.6%
Non-financial investors	1.3	1.1	0.1	1	82.6%	6.4%	72.4%
Local gov.	0.9	0.8	0.1	0.2	85.1%	10.0%	19.6%
State gov.	0.5	0.4	0	0.3	70.2%	9.2%	48.4%
Non-EA central banks & gov.	0.4	0.3	0	0.3	75.0%	3.5%	67.3%
Unallocated	0	0	0	0	70.4%	11.8%	36.7%
Total	1499.2	937.1	161.4	538.1	62.5%	10.8%	35.9%

by the share of renewables in electricity production (i.e. 35%, the TAC for NACE D35.11).

The second group of activities comprises transmission, distribution and storage of electricity/energy. The TAC for both NACE sectors D35.12 and D35.13, respectively transmission and distribution of electricity, is equal to 100% as the interconnected European System of transmission and distribution of electricity meets the technical screening criteria (source: European Commission-Joint Research Centre), with the sole exception of the portions connecting e.g. carbon intensive power plants to the grid. Storage activities are associated no particular NACE code.

The third group of activities covers biogas and biofuels, as well as low-carbon gases. The TAC for NACE D35.21 'Manufacture of gas' is equal to 1%, corresponding to the spending on biogas and biomethane projects over total global spending on gas (2020 data, source: International Energy Agency). As for hydrogen and other low-carbon gases, the TAC associated with relevant NACE sectors is set to zero given the negligible share of projects related to hydrogen and low-carbon gases (as well as CO2 capture and storage, see below) over all projects related to fluids (F42.21) and all activities related to the distribution of gaseous fuels (D35.22) and transport via pipelines (H49.50).

The fourth group of activities in the Energy section relates to heating and cooling. The TAC associated with NACE D35.30 'Steam and air conditioning supply' is equal to the share of renewable energy (incl. derived heat) used for heating and cooling in the EU, i.e. 21% (source Eurostat). The TAC activity for activity 4.15 is equal to 31.5%, owing to the fact that a district heating and cooling system is defined as efficient (green) if it uses at least 50% renewable energy (or waste or cogenerated heat). The TAC activity corresponds to the mean between the following two scenarios: (1) aligned installations are all using a share of 100% renewables, in this case the TAC activity would be 21%, and (2) aligned installations are all using a share of 50% renewables, in this case the TAC activity would be 42%. The resulting TAC activity is equal to (21+42)/2=32. Another relevant NACE sector for this group of activities is D35.11 (see above). Finally, NACE F43.22 'Plumbing, heat and air-conditioning installation' is relevant for the installation and operation of electric heat pumps. The TAC for this NACE sector is equal to 12%, i.e. the share of heat pumps over all installed heating and cooling units in the EU (source European Commission).

A.4. Water supply; sewerage, waste management and remediation activities

The first group of activities in this section relates to the construction, extension or renewal of water collection, treatment and supply systems. Relevant NACE sectors for these activities are E36 'Water collection, treatment and supply' and E37 'Sewerage'. The TAC for these NACE sectors is set to zero given the breadth of the sectors and the strictness of the technical screening criteria in terms of e.g. net energy consumption and infrastructure leakage.

The second group of activities relates to waste. The TACs for NACE E38.11 'Collection of non-hazardous waste' is equal to 38%, i.e. the share of recycled waste in the EU (2018 data, source Eurostat). The TACs for NACE E38.21 'Treatment and disposal of non-hazardous waste' is equal to 2%, as this NACE sector includes the composting of bio waste, and currently only 40% of bio waste (around 5% of total waste) is effectively recycled into high-quality compost and digestate. The TAC associated with NACE E38.32 'Recovery of sorted materials' is 100%.

The third group of activities relates to CO2 transport and storage. Relevant NACE sectors are F42.21 'Construction of utility projects for fluids' and H49.50 'Transport via pipeline', both also relevant for energy activities (see above) and E39.00 'Remediation activities and other waste management services'. The TAC for these three sectors is equal to zero owing to carbon capture and storage technologies not having yet reached industrial scale.

Finally, NACE sector F42.99 'Construction of other civil engineering projects n.e.c.' is relevant for all the three groups of activities in this section. It is associated with a TAC equal to zero given the very small share of green projects in this sector compared to the universe of civil engineering projects.

A.5. Transport

The first group of transport-related activities relates to land transport. For NACE sectors H49.10 'Passenger rail transport, interurban' and H49.20 'Freight rail transport', the TAC is equal to 56%, corresponding to the share of electrified railway lines over total in the EU (2019 data, source Eurostat). The TAC for NACE H49.31 'Urban and suburban passenger land transport' is equal to 2%, calculated as the share of electric buses and trams over total buses and trams in the EU (2019 data, source Eurostat). The TAC for NACE sectors H49.32 'Taxi operation' and H49.39 'Other passenger land transport n.e.c.' is equal to 0.3%, i.e. the share of battery electric vehicles (plug-in hybrid electric vehicles do not meet the technical screening criteria) over the total stock of passenger cars in the EU (2019 data, source Eurostat). The TAC for NACE sectors related to freight transport services by road (H49.4.1, H53.10 and H53.20) as well as the associated TAC Activity are equal to 0.2%, i.e. the share of electric lorries over total in the EU (2019 data, source Eurostat).

The second group of activities relates to water transport. The TACs for relevant sectors, including for example inland passenger (H50.30) and freight (H50.40) water transport, are all set equal to zero given the negligible share of vessels currently satisfying the technical screening criteria (e.g. hybrid and dual fuel vessels deriving at least 50% of their energy from zero direct CO2 emission fuels or plug-in power).

A number of NACE sectors covering renting and leasing are also relevant for passenger and freight transport activities. The TAC for cars and light motor vehicles (N77.11) is set to 0.3% (see above), the TAC for trucks (N77.12) is equal to 0.2% (see above), the TAC for water transport equipment (N77.34) is se to zero (see above), the TAC for other machinery, equipment and tangible goods n.e.c. (N77.39) is set to zero owing to the breadth of the sector, while the TAC for recreational and sports goods (N77.21) is equal to 0 as only few of the activities in this NACE sector are related to zero-emission transport.

The third group of activities in this section relates to transport infrastructure. The majority of the relevant NACE sectors for this group of activities are associated a zero TAC, given the very small share of green activities compared to the breadth of these sectors (e.g. M71.10 'Architectural and engineering activities and related technical consultancy' and M71.20 'Technical testing and analysis'). A TAC of 56% is associated with NACE F42.12 'Construction of railways and underground railways' (same as for the manufacturing of trains and for passenger an freight rail transport, see above). A TAC of 4% is associated with NACE sectors H52.21 'Service activities incidental to land transportation' and F42.13 'Construction of bridges and tunnels' and corresponds to the length of electrified railways over the total length of tracks and roads in the EU (2019 data, source Eurostat). Finally, the construction of low carbon airport infrastructure also involves NACE F41.20 'Construction of residential and non-residential buildings', which is assigned a TAC of 40% based on the approach described in the following section.

A.6. Construction and real estate activities

The first group of construction and real estate activities comprises the construction of new buildings and the renovation of existing ones. The TAC associated with relevant NACE sectors, namely F41 'Construction of buildings' and F43 'Specialized construction activities', is equal to 40%. This is the lower between the TAC Activity for the construction of new buildings and the TAC Activity for renovation of existing buildings.

The particularly large TAC Activity of 80% associated with the construction of new buildings is due to the fact that the Energy Performance of Buildings Directive (EPBD) requires all new buildings from 2021 (public buildings from 2019) to be *nearly zero-energy buildings* (NZEB). Based on relevant technical screening criteria, a new building is defined as green if its primary energy demand is at least 10% lower than the NZEB benchmark. By assuming that the primary energy demand is uniformly distributed between 50% and 100% of the NZEB requirements, the TAC is equal to (0.9 - 0.5)/0.5 = 80%. With respect to renovation activities, the technical screening criteria require a reduction in primary energy demand of at least 30%. The TAC Activity associated with renovation activities is based on the assumption that the improvement in primary energy demand due to renovation activities is uniformly distributed between 0 and 50%. It follows that the renovation TAC Activity is equal to (0.5-0.3)/0.5 = 40%.

The second group of activities in this section relates to the installation, maintenance and repair of energy efficient equipment, charging stations, instruments such as thermostats and smart meters, and renewable energy technologies. These activities are linked to several NACE sectors, e.g. F42 'Civil engineering' and the manufacturing of wood, paper, rubber, etc. All of these NACE sectors are associated a TAC of zero as the share of green activities within these very broad sectors is negligible.

Finally, the TAC for NACE L68 'Real estate activities' is equal to 15%, as the relevant technical screening criteria define a green building as one with has at least an Energy Performance Certificate (EPC) class A or belongs to the top 15% of the building stock in terms of energy efficiency. Notice that considering all EU countries, the share of EPC A buildings never exceeds 15% (in fact only in NL it exceeds 15% of the *total* certified buildings, which are a fraction of the total building stock).

A.7. Information and communication

Given the wide scope of the NACE sectors associated with these activities, namely J61 'Telecommunications', J62 'Computer programming, consultancy and related activities', and J63.11 'Data processing, hosting and related activities', as well as the specificity of the technical screening criteria for data centres and ICT solutions, these TACs are set equal to zero.

A.8. Professional, scientific and technical activities

These activities include research, development and innovation relevant for any other green activity, explicitly including carbon capture and storage, as well as professional services related to energy performance of buildings. Relevant NACE sectors are M71 'Architectural and engineering activities; technical testing and analysis' and M72.10 'Research and experimental development on natural sciences and engineering'. Their TAC is set to zero given the wide scope of these sectors compared to the comparatively limited number of green activities as identified in the other sections.

Appendix B. Transition-exposure coefficients: values and rationale

B.1. Fossil fuels

All NACE sectors classified in the fossil-fuel CPRS are associated a 100% TEC.

B.2. Manufacturing

With respect to manufacturing, the Taxonomy establishes technical screening criteria for DNSH to the objective of climate change mitigation when defining green activities from a climate change adaptation perspective. For some manufacturing activities, namely the manufacturing of cement, aluminium, iron and steel, carbon black, soda ash, and organic basic chemicals, the DNSH threshold corresponds to the median emission level of existing installations. This means that half of the plants are considered being causing significant harm from a mitigation point of view. As a consequence, we use a 50% coefficient to weigh exposures to relevant NACE sectors. For plastic manufacturing, the TEC is the complement to 1 of the relevant TAC, resulting in 93%.

The manufacturing of motor vehicles, boats and ships, as well as locomotives and rolling stock, and all transport activities (including passenger and freight, land, water, and air) can be assessed by considering all fossil-fuel-propelled transport means as risky assets. In practice, it amounts to taking the complement to one of the TACs for relevant NACE sectors, and using a 100% coefficient for exposures to the air transport sector (NACE H51).

NACE sectors related to the manufacturing, repair and maintenance of aircrafts, not included in the Taxonomy, are associated a TEC equal to 100% (e.g. C30.3 'Manufacture of air and spacecraft and related machinery') as there are technological challenges to the transition to low-carbon fuels for this type of transport.

B.3. Energy

Considering electricity production, we use the share of electricity generated from fossil-fuels, i.e. 39% (2019 data, source Eurostat) to weigh exposures to NACE sector D35.11.[22] Analogously, we use a coefficient of 29% to weigh exposures to NACE F42.22 'Construction of utility projects for electricity and telecommunications' (see description of the TAC rationale for this sector in the Appendix).

Considering heating and cooling activities, we use as coefficient for NACE sector D.35.3 'Steam and air conditioning supply' the share of derived heat that comes from fossil-fuels in the EU, i.e. 39% (2019 data, source Eurostat).

B.4. Transport

Considering the NACE sectors associated with Transport activities in the Taxonomy, their TEC is the complement to 1 of the relevant TAC whenever the NACE sector is linked to fossil-fuel-propelled transport. For example, the TEC for NACE sector N.77.11 'Renting and leasing of cars and light motor vehicles' is 99.7% as this is the share of internal combustion vehicles. Other sectors included in the Transport section but with no exposure to fossil fuels have a TEC of zero.

NACE sector H.51 'Air transport' and related sectors, not included in the Taxonomy, are associated a TEC equal to 100% as there are technological challenges to the transition to low-carbon fuels for this type of transport.

B.5. Construction and real estate activities

Considering buildings, while the construction of new buildings in the EU has to abide a strict regulation in terms of energy efficiency (see Appendix A), the EU building stock has ample margins for decarbonization. As coefficient for NACE L68 'Real estate activities' we take 70%, i.e. the share of the building stock which is defined as excessively energy inefficient, or significantly harmful, in Appendix B of the Climate Delegated Act (DNSH technical screening criteria for mitigation).

Appendix C. Logic of TAC and TEC values across NACE codes with various digits

The flow chart in Fig. 3 illustrates the logic that applies to TACs (Taxonomy Alignment Coefficients), TELs (Taxonomy Eligibility Indicators), TECs (Transition Exposure Coefficients). Note that only NACE sectors which are eligible, i.e. with TEL = 1 can have TAC > 0. All the sectors with TEL = 0 have TAC = 0.

[22] It should be noted that electricity production from natural gas may in some instances be considered a transitional activity, hence not a harmful activity, and even a green activity. For simplicity, and in the absence of thresholds, we consider all electricity generation from fossil-fuels as risky in a climate transition risk perspective.

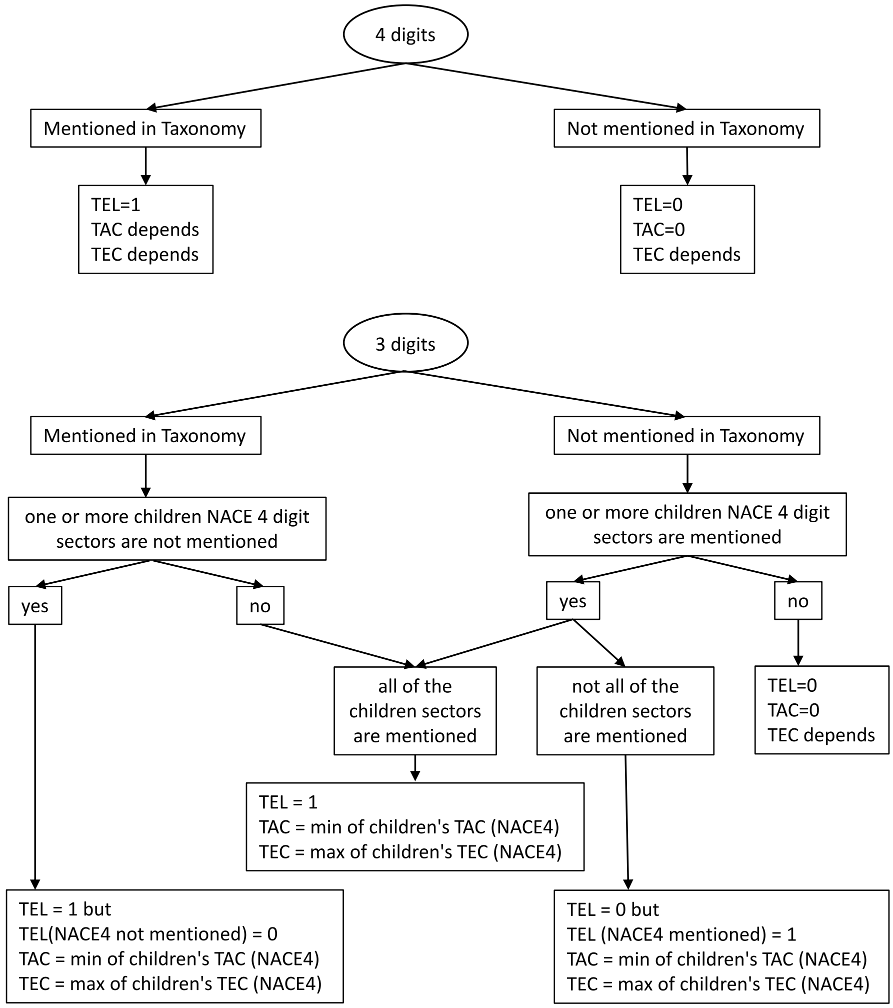

Fig. 3. TEL, TAC and TEC for NACE sectors with various digits.

Appendix D. Additional tables

See Tables 5–9.

Appendix E. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.irfa.2022.102319.

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