Financial carbon footprint: calculating banks' scope 3 emissions of assets and loans

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Abstract
Financial institutions play a crucial role in achieving the 2015 Paris Climate Agreement. They can manage capital flows for financing the required transformation towards a decarbonized industry. Currently established policy programs and regulations at European and national level increasingly address financial institutions to make their climate warming impact measurable and transparent. However, required science-based assessment methods have not been sufficiently developed so far. This paper discusses methodological opportunities and challenges for measuring carbon footprints of financial institutions. Based on a scientific case study undertaken with the German GLS Bank, the authors introduce an innovative method for quantifying greenhouse gas emissions from a bank's asset with a focus on loans. The authors apply an input/output database to calculate greenhouse gas (GHG) intensities and allocate them with bank's loans and investments. Moreover, the paper provides insights of calculating avoided GHG emissions initiated by a bank's investment and loans. In conclusion, a high degree of consistent and standardized assessment methods and guidelines need to be developed and applied to promote comparability and transparency.

Introduction
Global climate change is one of the largest challenges for society, politics, business and finance in the twenty-first century. Numerous political steps have been taken at international level to curb global warming and to enable a transition towards sustainable societies. Maybe the most critical milestones are the adoption of the *United Nations Sustainable Development Goals (SDG)* and the *Paris Climate Convention in 2015*.

Climate protection requires both a gradual and disruptive transformation in technology, business, finance, politics and society. All social and economic actors are challenged to find and implement solutions. In this regard, banks and other financial market player have a special role. As it is unlikely that state budgets alone will suffice in financing sustainable transition, they manage and shape the required capital flows.

Over the last decade green bonds are on the rise. The use of proceeds from green bonds worldwide in 2019 indicates that the most relevant sectors are energy (31 %), buildings (30 %) and transport (20 %) (Climate Bonds Initiative, 2020). Moreover, banks are increasingly considering sustainability as a risk factor for their business activities, including climate impact risks themselves and risks arising from the transformation towards a sustainable economy.

Actors from politics and science refer to the financial institutions as a critical stakeholder for the Great Transformation (Jeucken, 2010; Schneidewind, 2018; Urban & Wójcik, 2019). The EU Commission has set up a *High Level Expert Group on Sustainable Finance* that suggested a framework for the development of an EU strategy for sustainable finance (EU High-Level Group on Sustainable Finance, 2018). Based on the results of the expert group, an EU Action Plan on Sustainable Finance has been established that focuses on 1) reallocating capital flows towards sustainable investments, 2) addressing financial risks arising from climate change, environmental degradation and social impacts as well as 3) promoting transparency and a

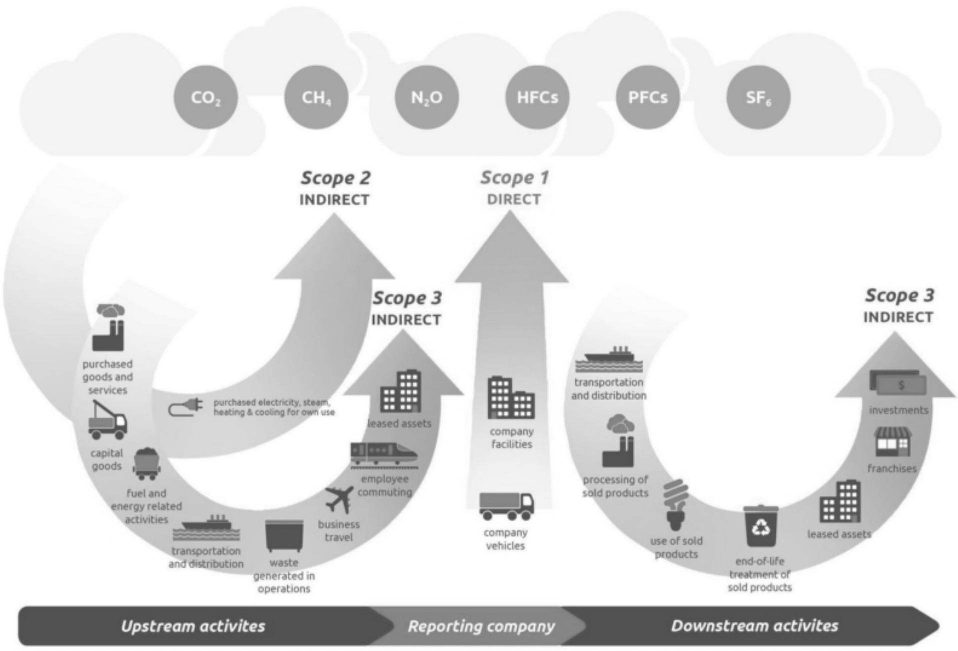

Figure 1. Scope categories according to GHG Protocol Corporate Value Chain (Greenhouse gas protocol, 2011).

long-term approach to financial and economic activities. The overall aim is to establish a taxonomy within the EU that standardizes sustainable financial products and provides greater security for investors (European Commission, 2018).

To this end, a better understanding of the environmental and societal impacts of financial business operations is called for, as this would also allow the players to manage them in a sustainable manner. A crucial challenge is to robustly quantify the impacts of investments and to present the results in a way that is transparent and comparable. However, methods that incorporate a holistic impact assessment of environmental and societal impact of banks' business operations are highly complex and still under development.

Nevertheless, many banks already report their climate warming impact with the environmental indicator "Carbon Footprint". According to the GHG Protocol Corporate Standard (*Greenhouse gas protocol*, 2011), GHG emissions of a company are classified into three areas, or scopes. Scope 1 emissions are direct emissions of the bank from its own or controlled sources. Scope 2 emissions are indirect emissions from purchased energy. Scope 3 emissions comprise all indirect emissions (not included in scope 2) that arise in the value chain of the bank's business activities. A bank's assets are attributed to scope 3 in this scheme (see Figure 1). The authors of this paper argue that investments and loans comprise the most relevant climate warming impact of a bank (captured in category 3.15 according to (*Greenhouse gas protocol*, 2011).

However, scientifically sound evaluation methods and data required for this purpose have not yet been sufficiently developed and standardized. Instead, initial methods for assessing the climate impact of loans and investments are currently being developed and tested in open network initiatives, such as the *PCAF – Partnership for Carbon Accounting Financials* (Giel Linthorst & Mark Schenkel, 2018, 2019a; Wouter Meindertsma et al., 2017). PCAF is an initiative that originates from the Dutch Carbon Pledge. PCAF has been under development since 2015 and provides a GHG accounting standard explicitly for financial assets. The overall idea behind PCAF is that the Carbon Footprint of a portfolio is the basis on which financial institutions can carry out scenario analyses, set targets and disclose progress of portfolio decarbonization. With 58 participating institutions from Europe, Asia, Africa, North and Latin America, the PCAF developed an assessment methodology that has been applied on a total volume of around EUR 3.15 trillion[1] (PCAF, 2020). The methodology is freely available for financial institutions and other stakeholders (Luis Mark et al., 2019)[2].

The Dutch Triodos Bank for example, has applied the standard to calculate their Carbon Footprint (induced GHG emissions), Carbon Handprint (avoided GHG emissions) and sequestered emissions (emissions that have been recaptured in carbon sinks, e.g. through afforestation) (Triodos Bank, 2018). In total, 68 % of Triodos Bank's investment volume in 2018 have been captured, leading to net positive effect on the climate (more GHG emissions are avoided and sequestered than produced). The focus was placed on the most carbon-intensive business areas, including organic farming, sustainable property, private mortgages, retail banking, social housing, healthcare, SRI funds, renewable energy and nature development and forestry (Luis Mark et al., 2019).

While some impacts could be based on actual or so-called primary data, others have been calculated based on physical input data captured by their loan managers. In the sector *organic farming* for example, data on the area of financed farms have been collected and combined with GHG emission factors per hectare farmland. The attribution to the bank's own scope 3 uses a financial denominator as seen in Equation 1 (attribution

1. PCAF communicates that USD 3.5 Trillion have been captured with the PCAF related assessments. The amount has been converted in EUR using the exchange rate of 13.03.2020 provided by https://www.finanzen.net/waehrungsrechner/us-dollar_euro (accessed on 13.03.2020).

2. Further information about the case studies can be found on the following website: https://carbonaccountingfinancials.com/financial-institutions-taking-action#best-practice-examples (accessed on 13.03.2020).

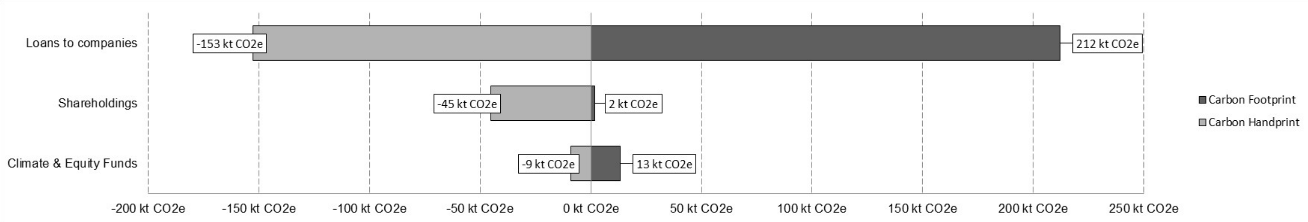

Figure 2. Carbon Footprint & Carbon Handprint of GLS Bank Assets (Climate & Equity Funds, Shareholdings, Loan Portfolio).

of financed farms to the scope 3 emissions of Triodos bank – own compilation).

$$Carbon\ Footprint_{farms} = \frac{CO_2\ equivalents}{hectares} x\ hectares$$

$$x\ \frac{Outstanding\ Triodos\ loan\ \&\ investment}{Balance\ sheet\ total} \quad (1)$$

The denominator here is the total balance of the company that was financed. Defining this denominator is a crucial step in any impact assessment of investments as it reflects the responsibility of the financing institution. It is also one additional data point that is not necessarily already captured for every asset.

This paper describes key results of a research project on GLS Bank's climate impact of a large loan portfolio where neither accounting data (balance or value added) of loan recipients nor any physical data was available. It is discussed how modelling can help to estimate the effects instead, but also what limitations come with such an approach and how they might be reduced. These limitations will always be inherent to any method that is not based on primary data by companies. However, large portions of the global loan volume are associated with smaller and medium sized companies that usually do not have the means or the knowledge to estimate their own company's Carbon Footprint. Estimating robust results in these cases is therefore an important prerequisite of managing portfolios in a sustainable way.

Case Study of GLS Bank assets

The aim of the research project was to account scope 3 greenhouse gas (GHG) emissions of the GLS Bank's financial and investment portfolio (3.15 investments). The GLS Bank is one of the first banks in Germany with a social-ecological business model and has been financing sustainable projects and companies for over 40 years. GLS Bank has set itself the aim of improving the transparency of their climate impact. In this context, the GLS bank assigned the Wuppertal Institute to determine the Carbon Footprint (CF) of its financial and investment portfolio with special emphasis on loans, climate funds and shareholdings. In addition, avoided emissions were calculated as well (in form of a Carbon Handprint), but limited to investments that have a clear cause-effect relationship in that regard (such as renewable energies, low-carbon transport, energy efficient housing and organic agriculture).

GLS Bank's loans encompass renewable energies, sustainable business, nutrition, housing, education & culture, social welfare & health. Other assets investigated are the Climate Funds (including investments into Green and Sustainability Bonds) as well as shareholdings for renewable energy subsidiary companies (*GLS Energie AG* and *GLS Beteiligungsgesellschaft*). In total, about 55 % of GLS Bank's balance sheet total has been covered by the research project (not included were for example loans to other banks that represent 27 % of the bank's balance alone). This paper focuses on the loan portfolio (EUR 3.9 bn) but also summarizes the results in the other two areas that are described in more detail in an upcoming full report[3].

The results are based on mixed methods that range from the use of primary data (shareholdings and some assets in the climate funds), sampling (estimates compared to available data for similar companies), global GHG intensities for production and newly developed models (bottom-up LCA data and top-down Input/-Output tables). In total, a Carbon Footprint of 227 kilotons[4] CO_2-equivalents (or kt CO_2e) was attributed to the bank itself. By comparison, a negative Footprint or Carbon Handprint of -207 kt CO_2e could be associated with investments that avoid GHG emissions (see Figure 2).

This attribution assumes that the bank is only responsible for parts of both the Footprint and Handprint, as many emissions from the up- or downstream of the value chain cannot be attributed to the bank alone. This risk of double counting is managed from the perspective of the asset recipient (e.g. the loan recipient) whose emissions were further disaggregated into scope 1, scope 2 and scope 3 emissions. While 100 % of the scope 1 emissions were attributed to the Scope 3 investment of the bank (in relation to e.g. the volume of a loan that is still owed), only 50 % of the scope 2 and none of the scope 3 emissions were attributed. Attributing 50 % for scope 2 is a common assumption when there is not enough information on the actual exchange of energy within a portfolio (scope 2 representing the indirect emissions from energy consumption produced by other entities). A more accurate attribution rule is up to future research, but will be likely based on an analysis of the portfolio's distribution of energy producers and consumers.

However, applying a general 100/50/0 attribution rule influences the results to a high degree. The net emissions of the loan portfolio for example show a net positive for the GHG emissions from the perspective of the bank, but a net negative from the perspective of all actors, therefore a higher effect for GHG emission reduction than production (see Figure 3).

Table 1 shows the results of the loan portfolio in more detail, while accounting for the fact that some loans could be directly associated with investments into renewable energies, even if the loan recipient's primary economic activity is in another sector. This distinction was achieved with the help of a R-script, that filtered the loan data for key words.

3. The full report is currently under review and will be published in 2020.

4. The authors refer to metric tons, which correspond to 1,000 kilograms, or approximately 2,204 pounds.

The range of GHG intensities (tons of CO_2-equivalents per EUR value added) for each asset is very broad and mainly depends on the sector an investment relates to (mostly assets under investigation) or measures that are financed (mostly Green and Sustainability Bonds). Table 2 shows the nominal efficacies for investments into each asset class in form of the median as well as the weighted average (in relation to the investments by the bank). It is also important to note though that a significant share of the investments bank show a clear focus on social affairs rather than environmental issues. Managing these assets from the perspective of their Carbon Footprint alone might therefore not be a sufficient portfolio management strategy.

The following sections focus on the loan model, but also on the lessons learned that the authors derived from quantifying the GHG emissions of such a large and diversified loan portfolio. It is investigated how the model results can be improved, but also how further research could facilitate portfolio management towards low-carbon financing.

Loan Model

All loans in the asset pool are provided to German entities (such as small businesses). It is therefore safe to assume that stimulated business activities from those loans take place in Germany for the most part as well (e.g. organic farming). The

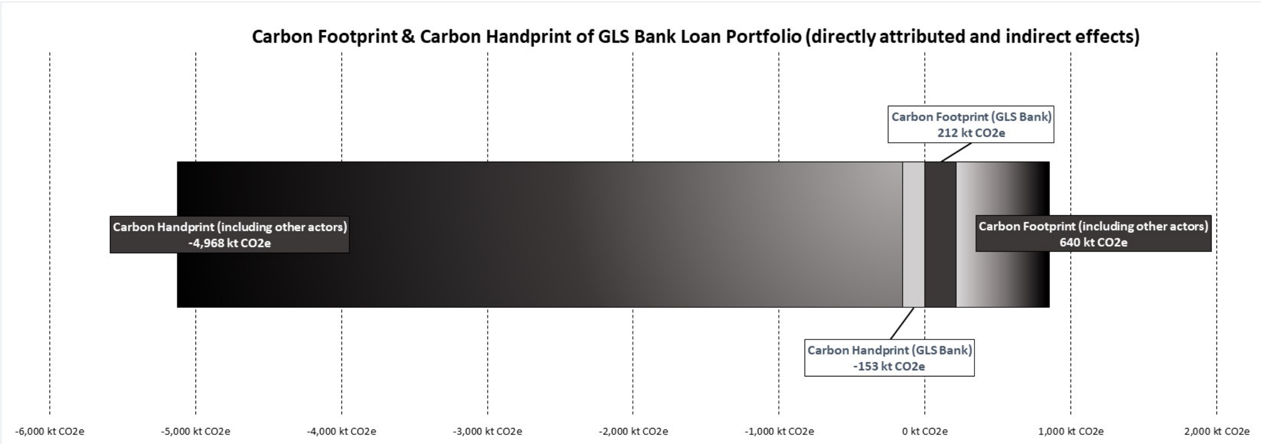

Figure 3. Carbon Footprint & Carbon Handprint of GLS Bank Loan Portfolio (directly attributed and indirect effects).

Table 1. Carbon Footprint and Carbon Handprint Results of the loan portfolio in relation to loan recipient.

Bank Industry Class (#BIC)	Carbon Footprint (GLS Bank)	Carbon Footprint (including other actors)	Carbon Handprint (GLS Bank)	Carbon Handprint (including other actors)
01 Energy	19 kt CO_2e	120 kt CO_2e	-152 kt CO_2e	-4,939 kt CO_2e
02 Nutrition (including investments into PV & WE)	66 kt CO_2e	227 kt CO_2e	-1 kt CO_2e	-24 kt CO_2e
03 Sustainable Living (including investments into PV & WE)	32 kt CO_2e	44 kt CO_2e	0 kt CO_2e	-2 kt CO_2e
04 Housing (including investments into PV & WE)	49 kt CO_2e	86 kt CO_2e	0 kt CO_2e	-1 kt CO_2e
05 Education & Culture (including investments into PV & WE)	17 kt CO_2e	41 kt CO_2e	0 kt CO_2e	-1 kt CO_2e
06 Health & Social Affairs (including investments into PV & WE)	29 kt CO_2e	122 kt CO_2e	0 kt CO_2e	-1 kt CO_2e

Table 2. Nominal efficacies of Scope 3 investments.

Asset Class	Weighted Average [t CO_2e p. million EUR]	Median [t CO_2e p. million EUR]
Equities (Equity & Climate Funds)	284	56
Bonds (Equity & Climate Funds)	190	116
Shareholdings	193*	–
Loan Portfolio	53	44

** Estimation based on 9.3 million EUR investments (GHG emissions calculated from actual energy production).*

loans have already been coded by the bank according to their own classification system (#BIC). This system consists of 4-digits for over 72 different industries with the first digit relating to different dimensions of sustainability such as renewable energy, nutrition or social affairs & health. The goal of the model was to calculate scope 3 emissions of loans along these 72 industries, but also to estimate avoided emission where a reliable cause-effect-chain for GHG reductions could be anticipated. An additional requirement was to provide emission from the perspective of the 3 GHG scopes of the loan recipients, as this data was later used to calculate the 1.5 degree combability of the loan portfolio of the bank (conducted by other researchers and not covered in this paper).

Since further specific data on loan recipients was scarce or not available at all, it was decided that a macro-economic based model would be the best approach to come up with robust lump factors for GHG emissions for each loan category. A simple solution for this problem would be to only look at the current state of one economy, using the direct GHG emissions of each sector in an environmental extended national input-/output table[5] and match these sectors with the industries in the bank's classification. However, it was determined that this approach would lead to less robust results, as many effects that are caused by economic activities take place somewhere else in the value chain. Industries are interlinked and indirect emissions might be a lot higher than the direct emissions from the local combustion of fossil fuels and other sources. A new model was developed that focused on the causes for emissions of additional economic activity (such as buying raw materials) rather than limiting on the outcome (e.g. emissions of a plant).

Some IO-Models are not only environmental extended but also multi-regional, allowing to track economic activities between countries and between industries within countries (MRIO tables and models). WI-SEEGIOM[6] is such a model that is originally based on the MRIO-Table of exiobase, but was further developed to model various changes in the global economy Figure 4. Exiobase provides fully interconnected foreign trade relationships, 163 industries or 200 product groups, 49 world regions and more than 200 abiotic and biotic materials as well as 59 energy carriers. It allows to link the economic activity of trade, production and consumption to both monetary (e.g. gross value added or personnel costs) and physical values (e.g. raw material extraction or GHG emissions to air). In particular, the model enables to track changes in the global economy when investments are re-allocated or additional products are produced or consumed.

Using WI-SEEGIOM as starting point, several steps were necessary to match GHG intensities with the bank's balance of loans in its portfolio of industries. Figure 4 provides an oversight of these modelling steps that resulted in the calculation of both the Carbon Footprint and Carbon Handprint of the loan portfolio of a bank.

The first two steps are limited to disaggregation and allocation procedures within the MRIO-Model (MRIO-M). First, vectors are generated that represent an additional output of EUR 1 million value added for each product group, also tracking the inputs and outputs of the entire economy. As a result, physical values such as GHG emissions are allocated to the targeted industry itself (representing the direct output), but also to related economic activities in the other industries around the world (representing the indirect output from the entire value chain). In the second step, these vectors are also allocated to effects within Germany (DE) and to the rest of the world (RoW), mirroring the global balance of inputs and outputs of monetary and physical values. Germany is chosen because the loans in the asset portfolio of the bank are restricted to entities in this country.

Afterwards, characterization factors for the global warming potential over 100 years (GWP 100a) are applied to emissions for CO_2, CO, CH_4, N_2O and SF_6 (emissions from other greenhouse gases such as Hydrofluorocarbons were neglected for the model). The characterization factors (multiplied with the amount of gas in the MRIO-M) stem from the latest IPCC report (IPCC, AR 5). In relation to the additional requirement of providing GHG effects along the different scopes of the GHG protocol (see Figure 1), it was necessary to allocate the overall emissions of each industry in Germany to direct emissions (scope 1), indirect emissions from energy provision (scope 2) and other indirect emissions (scope 3; rest of emissions). Since a MRIO-T is based on national accounts, it is not possible to allocate the scopes in a way that is fully consistent to the requirements for a corporate carbon footprint. However, it was assumed that emissions within the industry in question represent scope 1 emissions to a large degree without risk of double counting. Scope 2 emissions on the other hand can be associated with emissions from related economic activities for electricity consumption and the use of fossil fuels. All other emissions were therefore shifted into scope 3, representing emissions from other actors of the value chain (not directly associated with bank loans).

At this point, all product groups in the MRIO-M are associated with GHG intensities (GHG_I in tons per million EUR) for each of the three scopes. These intensities have then been matched to the bank industry classification (#BIC) by the GLS Bank. A direct matching (1 GHG_I for 1 #BIC) was only possible in very few cases but covered more than 80 % of the credit volume (mainly loans for renewable energies). Most cases related to the use of one GHG_I for several #BICs (1:n), since many of the bank's classes relate to questions of ownership and corporation type rather than economic activity (e.g. different types of schools or non-profit versus commercial carriers for social services). The remaining matches were either deemed to be highly inaccurate (9 cases where no other method of matching was viable) or required additional attributional steps to ensure a higher level of robustness (n:1). The latter was achieved by matching several product groups of the MIRIO to one #BIC, e.g. by means of economic allocation (share of value added) or calculating the arithmetic mean (for e.g. processing of different food products).

The four #BICs for agriculture required additional modelling before they could be matched. Here, a separate model was created that represents the production of food (crops, vegetables, animals and animal products) in Germany by conventional as well as organic means (in order to both calculate the current Carbon Footprint but also to estimate potential savings). Using

5. An approach that for example Rabobank used in the description in their method in Giel Linthorst & Mark Schenkel, 2019b, p. 80.

6. WI-SEEGIOM: Wuppertal Institute – Socio-economically and Environmentally Extended Global Input-Output-Model.

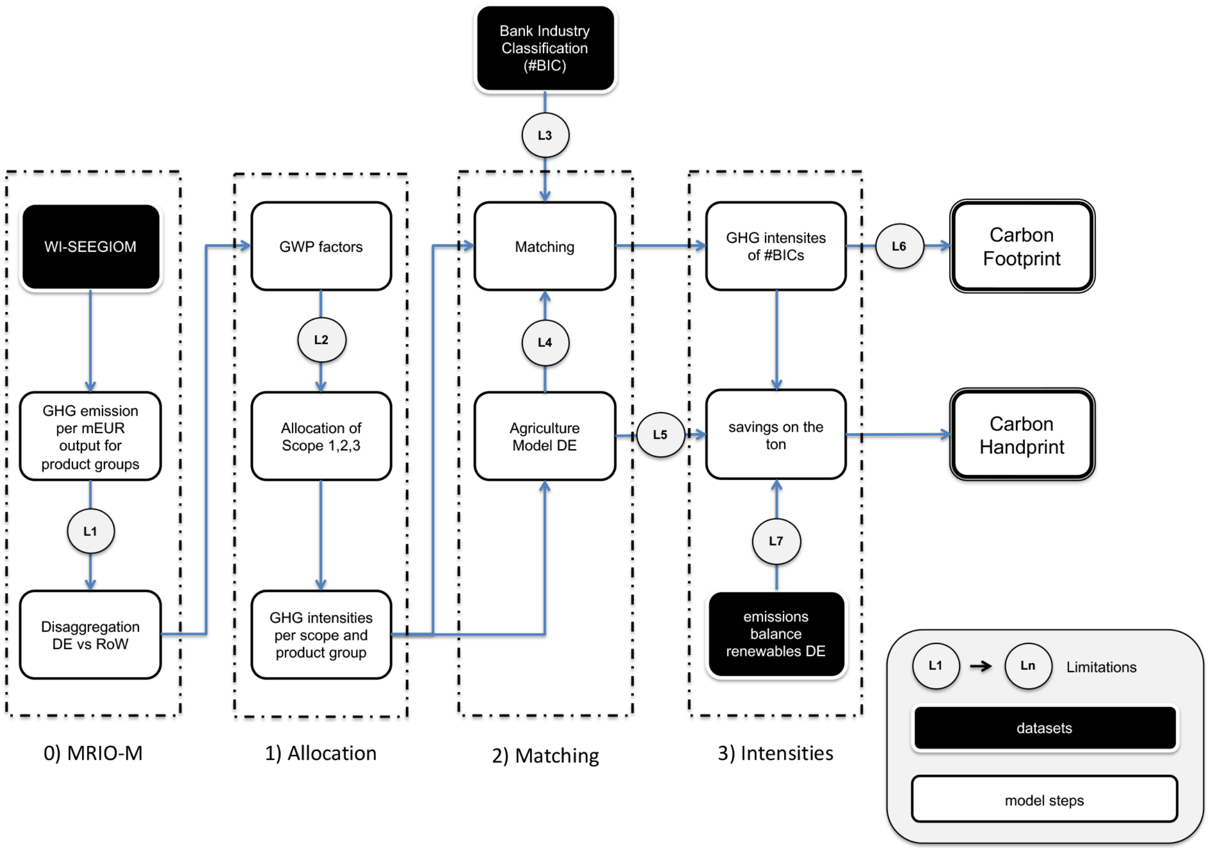

Figure 4. Model framework and model steps (see section on limitations for L1 to L7). (L1: disaggregation level; L2: accuracy of allocation ; L3: quality of compability; L4: completeness of statistics; L5: accuracy of LCA factors; L6: attribution to bank; L7: lack of physical data.)

Table 3. GHG intensities according to the original MRIO-Model and after integrating data on the organic food industry in Germany (source: own calculation).

Type	Scope 1	Scope 2	Scope 3
	[t CO_2e/million EUR]	[t CO_2e/million EUR]	[t CO_2e/million EUR]
Combination (MRIO-M)	29	598	1,095
Organic Production	26	584	1,055
Conventional Production	33	629	1,163
Savings on the ton	-6	-44	-108

the GHG intensities in the MRIO-M as basis (which combines both means of production) it was possible to allocate relative savings as well as additional GHG emissions for each product group and production type. Literature for generating the model stemmed from the German Ministry of Food and Agriculture (BMEL, 2019), the German federation of the organic food industry BOLW (BOELW, 2019), and a recent Nature article on the greenhouse gas impacts of converting food production in the UK (L. Smith et al., 2019; L. G. Smith et al., 2019). While some product groups show higher GHG intensities when produced organic, the overall effect results GHG savings as Table 3 shows.

Other GHG savings were assumed to result from investments (here loans) into renewable energies. The authors tested different approaches (e.g. bottom-up modelling within the MRIO-Tables based on LCAs) but decided in the end to opt for a straight-forward solution based on other data. The German Federal Agency for Environment UBA annually reports GHG savings in Germany from renewable energy (Lauf et al., 2019). These studies incorporate the individual replacement of conventional energy carriers with renewable energies based on their dispatchability (which energy carrier is most likely to be replaced and to what extent). Using this UBA study as well as a previous study on GHG savings from decentralized renewable energy production (Lanz et al., 2011), the authors calculated so-called "savings on the ton". Savings on the ton (in tons of savings per tons of emissions) are applied directly to the GHG intensities in the MRIO-M and provide a quick and robust estimation of GHG savings on the scale of total value added. Also applied on other renewable assets in the project (shareholdings) it could be shown that this simplified approach leads to robust results compared to LCA modelling of the actual electricity production.

With all models and characterization factors in place, the authors then proceeded to calculate the overall Carbon Footprint and Carbon Handprint. However, only parts of the overall effects for both Footprints are directly associated with the loan portfolio of the bank, as a significant share of the borrower's emissions can be associated with more than one source (leading to potential double-counting). Without more detailed information, the authors applied a flat 100/50/0 approach, allocating 100 % of the scope 1 emissions, 50 % of the scope 2 emissions and none of the scope 3 emissions to the overall volume of the credit balance of the bank. This attribution results in the GLS Bank being directly responsible for 25 % of the Carbon Footprint and 3 % of the Carbon Handprint. From the societal perspective, more emissions are avoided than emitted from activities directly (GLS bank) and indirectly (all actors including GLS Bank) linked to the loans in the portfolio.

Limitations from the loan model

The authors identified several limitations of the model. Some of these limitations are inherent to the method or accuracy of the data. These limitations can only be reduced by several iterative steps where results of the model are compared to actual data in published GRI reports or by comparing the MRIO-Tables of different time periods.

Others could be reduced or even overcome in due course as they benefit from additional emissions data, modelling or information in the loan data. Table 4 summarizes the limitations (see also L1 to L7 in Figure 4) and estimates the effects on the accuracy of the model. The solutions to the problems listed here are currently under investigation for future studies and will also be discussed in the outlook of this paper.

Outlook

The authors described a viable approach to estimate the Carbon Footprint (and partly even the Carbon Handprint) from basic information in a loan portfolio. The novelty of the approach lies in the higher level of detail when it comes to the separation into different emission scopes and to the matching with different types of loan recipients. The here described intensity factors could also be used on the loan portfolio of another bank without much effort and, to some degree, on any type of Scope 3.15 investment. Although the developed model is no replacement

Table 4. Description and impact of model limitations (source: own compilation).

Nr	Issue	Effects on accuracy of model	Possible solution
L1	The disaggregation into only two regions (DE/RoW) results in higher uncertainties between sectors in the rest of the world.	Small deviations for emissions that are not attributed directly to the bank (Scope 3 emissions of loan recipients).	Disaggregation into all regions or at least between Germany, Europe and the rest of the world.
L2	Non-conformity between scopes of companies (GHG protocol) and product groups in MRIO-Tables.	Small deviations of GHG intensities per scope for industries with low emissions from energy consumption, but medium or even large deviations for industries with high energy demand.	Samples of real GRI reports of companies in crucial industries could provide a more specific allocation key for scope 2 versus scope 1 and scope 3 emissions.
L3	Low compability for some bank industry categories with MRIO product groups.	Some bank industry categories exhibit higher uncertainties regarding their GHG intensity. These represent a small portion of the current loan portfolio but could be more relevant in other portfolios (e.g. loans for recycling companies).	Matching is currently related to bank industries, while in fact many loans are not direct investments in that sector (e.g. buying a PV roof installation for a farm building). Future assessment could focus more on the purpose of a loan instead of the sector of the loan recipient (e.g. loans for machines or loans for raw materials).
L4	Product groups in the MRIO-M cover only parts of the overall agricultural sector in Germany. In addition, data on the value added by organic farming is not sufficient to capture all farming products.	Small deviations on the Carbon Footprint of loan recipients.	Inclusion of additional statistics for organic farming and further disaggregation on value added from products versus value added from services in the agricultural sector.
L5	Savings on the ton by agricultural products are based on very few products. Additionally, GHG effects are based on farming conditions in the UK.	Medium deviations on the Carbon Handprint of loan recipients.	Additional bottom-up modelling of farming products (in particular for fruits and processed food products) would improve data quality and reduce uncertainties for the Carbon Handprint.
L6	The attribution assumptions simplify the issue of double counting in GHG protocols. They therefore do not necessarily represent the responsibility of the bank (for both Carbon Footprint and Carbon Handprint).	Large deviations for both Carbon Footprint and Carbon Handprint. However, re-adjustment of reported values (e.g. with different shares of attribution) requires only minimum effort.	There is currently no attribution rule that is commonly agreed upon. Double-counting might be avoided by looking into more detailed loan data (in particular for portfolios with energy producers) or by clustering and weighting assets in the portfolio compared to the overall economy.
L7	Using the overall emission balance of Germany is inferior to using data of actual physical systems because investments, earnings and physical output are not directly proportional.	Small (electricity) to medium deviations (other energy providers) for the Carbon Handprint of loan recipients.	A bottom-up model that combines the emissions of different types of energy providers with reliable data on investments, earnings and labor costs could enhance the model by linking the physical output to the economic output.

for actual data from companies (in e.g. GRI reports), it might very well be used to manage loan portfolios in a way that results in lower GHG emissions or higher potentials for GHG avoidance. Applying the model for the first time, several limitations of the model could be identified that influence the results to different degrees. Further research is therefore needed to reduce potential uncertainties and to increase the robustness of the results.

One of the largest issues with the approach stems from its inherent logic. It is assumed that any loan to a company in one sector leads to economic activity in that sector alone while inducing emissions along its value chain. However, many loans are either a direct through-put into other sectors (e.g. paying for a machine provided by a third party) or are used as a financial intermediary (e.g. to pay for other loans or to invest into other companies). Relying solely on sector data therefore does not reflect the actual use of investments and their impact on the society. It might be that sectors with low intensities induce larger emissions based on their typical investments or the other way around. A solution to that problem is the extension of the loan data by including additional information on the purpose of a loan. This requires the introduction of a new module on investments that is attached to the former model and is applied whenever additional loan information is available. The authors already tested such an approach by searching the informal data of each loan (ca. 13,000 loans) for key words regarding the purchase or investment into photovoltaics or wind energy plants. While the approach improved the success rate, a more formal approach is called for. We suggest capturing the purpose of each loan in one of several classes for e.g. pure financial movements, purchase of machines, construction or purchase of buildings, investments and so on. The MRIO-M is then further disaggregated into more regions to also account for investments in other countries (e.g. purchase of electric machinery from China).

Another issue stems from the allocation (overall emissions to scopes) and attribution (effects that are attributed to the investing entity) of emissions. Relying on the MRIO-Tables limits the accuracy of the results up to the point that some loans show very unusual or even implausible intensity factors (at least from the perspective of corporate footprints). The authors suggest implementing means of validation via a sampling approach. A large data set of GRI data of companies (or even a survey of recipients) could be used to allocate the scopes individually for certain industries while also providing information on more sector-specific rules of attribution. While data in GRI reports is not reliable in terms of Scope 3 emissions (many relevant emissions are omitted for lack of data), only more accurate information on scope 1 and 2 emissions are necessary to complement the status quo of the model. For purpose of matching this primary data the MRIO-M results, a higher level of disaggregation is necessary (country by country at best) though, as larger comprehensive data sets might only be available for certain countries.

As a result, gathering differentiated primary data from bank's client for measuring carbon footprint and carbon handprint could be utilized for both, (1) portfolio management towards a decarbonized economy transition and (2) engagement activities with clients to improve their climate strategy and operations (e.g. in cooperation with scientific and consulting institutions). In this regard, applying a sophisticated assessment method for robust results need to be ensured. In order to increase transparency and comparability of bank's impact on climate, a standardization of methods and used input data need to be established. Impact assessment can then lead to robust comparison of bank's climate performance, and therefore accelerating competition between banks towards a decarbonized financial and investment portfolio. The authors argue that the sector standard PCAF is an expedient starting point for further development of measuring the impact of banks on the climate, but also society.

To this end, more environmental and social impact indicators need to be developed and applied to make trade-offs between different impact areas visible and manageable (e. g. one-sided focus on climate strategy and negative rebound effects on circular economy). However, in order to transform the perspective from "banks are part of the problem" to "banks are a key for the solution", a mind shift in banks business strategy is required. Exclusion criteria in investment and finance decisions (e.g. investing in fossil fuels) are called for, but also the development and introduction of best-in-class criteria (e.g. focusing on best in class clients or issuing green and social bonds). It is our belief that environmental, social and economic risk impact assessment forms the foundation for a directional transformation of the financial system – making sustainability a key decision criterion even in conventional banks operations.

Abbreviations

#BIC	Bank industry classification of GLS Bank
CF	Carbon Footprint
CH	Carbon Handprint
GHG	Greenhouse gases
IO	Input-/output
LCA	Life Cycle Assessment
MRIO	Multi-regional input-/output
MRIO-M	MRIO-Model
MRIO-T	MRIO-Table
PCAF	Partnership for Carbon Accounting Financials
SDGs	Sustainable Development Goals

References

BMEL. (2019). *BMEL-Statistik: Landwirtschaftliche Gesamtrechnung*. https://www.bmel-statistik.de/landwirtschaft/landwirtschaftliche-gesamtrechnung/

BOELW. (2019). *Zahlen•Daten•Fakten Die Bio-Branche 2019*. Bund Ökologische Lebensmittelwirtschaft e.V. https://www.boelw.de/fileadmin/user_upload/Dokumente/Zahlen_und_Fakten/Brosch%C3%BCre_2019/BOELW_Zahlen_Daten_Fakten_2019_web.pdf

Climate Bonds Initiative. (2020). *Distribution of use of proceeds from green bonds worldwide in 2019, by sector*. Statista.

EU High-Level Group on Sustainable Finance. (2018). *Financing a Sustainable European Economy: Final Report 2018 by the High-Level Expert Group on Sustainable Finance*. https://ec.europa.eu/info/sites/info/files/180131-sustainable-finance-final-report_en.pdf

European Commission. (2018). *Aktionsplan: Finanzierung nachhaltigen Wachstums*. European Commission. https://

eur-lex.europa.eu/legal-content/DE/TXT/PDF/?uri=CELEX:52018DC0097&from=EN

Giel Linthorst, & Mark Schenkel. (2018). *Platform Carbon Accounting Financials (PCAF) report 2018* [Report]. PCAF; Navigant.

Giel Linthorst, & Mark Schenkel. (2019a). *PCAF The Netherlands, report 2019* [Report]. PCAF; Navigant.

Giel Linthorst, & Mark Schenkel. (2019b). *PCAF The Netherlands, report 2019* [Report]. PCAF; Navigant.

Greenhouse gas protocol: Corporate value chain (Scope 3) accounting and reporting standard: supplement to the GHG protocol corporate accounting and reporting standard. (2011). World Resources Institute; World Business Council for Sustainable Development.

Jeucken, M. (2010). *Sustainable finance and banking: The financial sector and the future of the planet*. Earthscan.

Lanz, M., Fricke, B., Anthrakidis, A., Genter, M., Hoffschmidt, D. B., Faber, D. C., Hauser, E., Klann, D. U., & Leprich, D. U. (2011). *CO_2-Emissionsminderung durch Ausbau, informationstechnische Vernetzung und Netzoptimierung von Anlagen dezentraler, fluktuierender und erneuerbarer Energienutzung in Deutschland*. https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/4195.pdf

Lauf, D. T., Memmler, M., & Schneider, S. (2019). *Emissionsbilanz erneuerbarer Energieträger*. https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2019-11-07_cc-37-2019_emissionsbilanz-erneuerbarer-energien_2018.pdf

Luis Mark, Kaboo Leung, & Giel Linthorst. (2019). *Triodos Bank Greenhouse Gas accounting methodology*. Triodos Bank, Navigant.

PCAF. (2020). *Financial institutions taking action*. Overview of Institutions. https://carbonaccountingfinancials.com/financial-institutions-taking-action

Schneidewind, U. (2018). *Die große Transformation: Eine Einführung in die Kunst gesellschaftlichen Wandels* (Originalausgabe). Fischer Taschenbuch.

Smith, L. G., Kirk, G. J. D., Jones, P. J., & Williams, A. G. (2019). The greenhouse gas impacts of converting food production in England and Wales to organic methods. *Nature Communications*, *10* (1). https://doi.org/10.1038/s41467-019-12622-7

Smith, L., Kirk, G., Jones, P., & Williams, A. (2019). *Underlying data for a 100 % organic conversion study*. https://doi.org/10.6084/m9.figshare.6080333.v2

Triodos Bank. (2018). *Triodos Bank – Annual Report 2018*. https://annual-report-triodos.com/2018/servicepages/downloads/files/annual_report_triodos_ar18.pdf

Urban, M., & Wójcik, D. (2019). Dirty Banking: Probing the Gap in Sustainable Finance. *Sustainability*, *11* (6), 1745. https://doi.org/10.3390/su11061745

Wouter Meindertsma, Mark Schenkel, & Giel Linthorst. (2017). *Progress report of the Platform Carbon Accounting Financials (PCAF)* [Report]. PCAF; Ecofys. https://www.dnb.nl/binaries/PCAF_tcm46-360394.pdf

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