Carbon Footprint Accounting

Case study Brewery

Connekt

Topsector Logistiek

Acknowledgements

Carbon Footprint Accounting
Case study Brewery

A practical case study using the accounting framework for Carbon Footprint Accounting and Carbon Circularity Accounting

October 2020

Authors
Hans Keetman
Joost Diepenmaat
Remco van 't Veer

Contents

1 Introduction

The use of 'supply chain thinking' as a tool in the fight against climate change gives rise to a need for a form of accounting that can demonstrate the total CO_2e footprint of an end product (from raw material through to finished product). In the Greenhouse Gas Protocol (GHG) this calculation is laid down as the ultimate goal, albeit without there being any practical and affordable way of achieving such accounting within the chain.

In the logistics sector solutions have now been found (e.g. BigMile) that allow the Carbon Footprint Accounting system to be implemented easily by all supply chain partners. To begin with, various practical tests were performed based on low-tech solutions. This delivered a great deal of insight into the practical barriers and sensitivities that would form the ultimate constraints and starting points for a scalable (high-tech) solution.

It was important to offer a solution that was as accessible as possible, to allow parties to get started independently. There is then no excuse for not taking the first step, after which each party can seamlessly develop its approach, in terms of finesse and detail, at its own speed.

The experiences gained in the logistics sector will serve as an important reference for industry when it comes to setting up a practicable approach to carbon accounting. In the case of production processes, the calculation is performed on the basis of the 'recipe' for the product, including energy consumption. The raw materials and/or semi-finished products have a CO_2e footprint, which is indicated by the supplier or assumed on the basis of available indicators. The steps in the production process result in a new product with a mix of components, which are allocated, in accordance with the recipe, to determine an intrinsic CO_2e footprint for each production batch. Transport to the customer adds CO_2e to this figure. The result is a delivered product with its own CO_2e footprint.

A producer can start calculating, and gradually refine the process, without any further coordination with suppliers and customers. This will automatically lead to questions being put to major suppliers, resulting in the formation of a chain.

The introduction of assurance categories[1] (ranging from assumptions through to precise measured values) allows the data to be placed within a transparent assurance structure, which makes audits possible.

Thanks to these assurance categories, the barriers to getting started are extremely low: after all, it is permitted to work with any combination, from general indicators through to precisely measured data. For some components little will be known for the time being (e.g. in the case of purchased materials), while for others there will be precise knowledge of the CO_2e footprint (e.g. energy consumption).

Determining the assurance category structure for each raw material, the use of tangible fixed assets, people and transport means that this same structure can be used in the rest of the chain. When the carbon footprint is determined for a subsequent product, the CO_2e information for the components can therefore be referred to, including the assurance level of the data.

1 *Assurance categories categorize the quality of the input data, e.g. assumptions, estimates, measured or detailed.*

To achieve a circular carbon economy[2], it is important that this accounting approach is expanded to incorporate both assurance categories and the origin of the carbon. The latter reveals the impact of the materials used across the entire chain.

Sources of carbon

- Fossil source (e.g. petroleum);
- Biomass;
- Recycled product;
- From CO_2 source:
  - From the air;
  - From a process (the CO_2 may have been produced from a fossil source or using biomass to be converted into a useful product).

In June 2020, Connekt - on behalf of the Ministry of Infrastructure, Public Works and Water Management, as the organization responsible for implementing the Topsector Logistics Multi-Year Program - commissioned a case study from the manufacturing industry that could provide a basis for a concrete conceptual framework.

On the basis of the above the following research questions were formulated and will be answered in this document:

1. Is it possible - using standard resources - to perform a concrete CO_2e footprint calculation for a technical conversion process based on the data available at the company concerned?
2. If so, what insights result from this CO_2e footprint calculation in terms of gaining an understanding of and limiting this footprint (carbon dioxide emissions) and other forms of 'waste', such as unused capacity and lost time?
3. Is it conceptually possible to apply the lessons learned more broadly than within this company alone?
4. What overall conclusion can be drawn from the answers to these research questions?

2 A circular economy is an economic system in which raw materials are extracted sustainably, fewer raw materials are needed per product and raw materials are reused or processed into other products (recycling) as much as possible. Rubble from construction, for example, can be used as a foundation for roads, waste paper can be used again as a raw material for the paper industry and plastic bottles can be transformed into new plastic. In this way we move away from the linear economy, in which raw materials are extracted, used and discarded. Using plant and animal materials as renewable raw materials for products and energy (bio-based economy) can also be regarded as an important step towards making the circular economy carbon-neutral (source: RIVM (Dutch National Institute for Public Health and Environment)).

2 Research approach

The following starting points were taken as a basis when deciding on a suitable, representative case study relating to a technical conversion process:

- An SME that has clear, comprehensible operations and pursues a sustainability policy;
- A company with multiple end products (to allow the CO_2 allocation to various end products to be calculated);
- A company with multiple forms of CO_2 emissions (resulting from energy consumption and chemical processes);
- A company that - after signing a two-page confidentiality agreement - is prepared to cooperate with the case study and share its available data.

In the end the cooperation of a brewer with over 20 end products was obtained.

A key starting point of the study is that only source data available at the producer is used. The ultimate aim of the calculations is to allocate energy consumed (tons of CO_2 equivalent[3]) to end products (hectoliters and tons[4]). This involves using a coarse-to-fine approach:

- Allocation of emissions from energy consumption (12 months) to end products;
- Allocation of emissions from energy consumption to production batches;
- Estimation of emissions from raw materials used (emission calculator);
- Estimation of energy consumption of employees (including commuting).

The following are taken into account here:

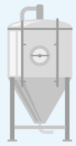
- Machines used (if data made available);
- Mixing ratios and durations (if data made available);
- Other resources, such as lubricants and cleaning agents (if data made available);
- Number of FTEs and commuting;
- CO_2e released from chemical conversion;
- By-products;
- Data completeness (e.g. energy data, production data) and consistency;
- Differences in the quality and assurance categories[5] of the data.

3 Also known as 'global warming potential', a measure relative to CO_2; methane (CH_4), for example, has 25 times the potential of CO_2. Referred to hereinafter as CO_2e.

4 The specific weight of beer is 1.0048 kilograms per liter.

5 Source: GHG Protocol scope 3 en Assurance (Peter de Wever, 2019)

The overall production process for beer is presented schematically below.

1 Storage of raw materials	2 Brewing process	3 Bottling	4 Storage of end products
• Barley • Hops • Yeast • Water • Carbon dioxide 	• Malting • Mashing • Boiling • Fermenting • Maturing 	• Bottles • Barrels • Cans • Other packaging 	

With the exception of water, the raw materials are delivered using vans and trucks. The brewing process takes place in batches, after which bottles and barrels are filled, packed and stored. Vans and trucks are used to deliver the end products.

A regular beer-brewing process is presented below.

1 Malting	2 Mashing	3 Boiling	4 Fermenting	5 Maturing
• Steep barley (water) • Dry grain (high temperature) • Result: malt	• Grind malt and • Mix (water) • Conversion of starch • Filteren • Result: wort and draff	• Boil wort (wort kettle) • Add hops • Cool (quickly)	• Top fermentation or bottom fermentation (temperature)	• Days to weeks

Products

Over the calculation period the producer brewed sixteen different beers.

Carbon footprint calculations

The data were initially calculated roughly so that a first draft of the 'management summary' could be drawn up for discussion with the producer. In this the total CO_2e emissions were allocated to the annual production in hectoliters. After the producer had verified this, additional information was provided on the production batches produced to allow the emissions to be allocated to the specific products on the basis of the recipe. To perform the calculations, the emission factors were looked up for all components that generate CO_2e emissions. Emission factors published at CO_2emissiefactoren.nl were used for this purpose. However, for a number of factors no clear sources were available. The factors used (with an indication of the source) were therefore included in the final presentation to the producer. This makes it easy to determine the basis for the calculations and to check whether other more reliable factors may be available.

The table below shows the emission factors used, including an indication of the source, for the eleven components. The components have also been broken down by GHG scope and the categories are indicated for the origin of the carbon and the data quality.

	Component	Carbon	Emission factor	Data quality	Comment	Source
SCOPE 1	Gas	Fossil	0.64 (kg CO_2e/Nm^3)	Gold	Natural gas	BigMile
	Carbon dioxide	CO_2 source	1000.00 (kg CO_2e/ton)	Silver		
	Fermentation process	Biomass	2.00 (kg CO_2e/hl)	Bronze		Producer
	Own transport	Fossil	3.23 (kg CO_2e/liter)	Bronze	Diesel	CO_2emissiefactoren.nl
SCOPE 2	Electricity	None	0.0001 (kg CO_2e/kWh)	Gold	Solar/wind	BigMile
SCOPE 3	Malt	Biomass	910.00 (kg CO_2e/ton)	Bronze	Malt	BIER 2012
	Hops	Biomass	5.08 (kg CO_2e/kg)	Bronze		BIER 2012
	Bottles	None	0.22 (kg CO_2e/stuk)	Silver	Purchasing to replace unreturned bottles	BIER 2012
	Crown caps	None	0.0025 (kg CO_2e/stuk)	Silver		BIER 2012
	Labels	None	0.0016 (kg CO_2e/set)	Silver		BIER 2012
	Commuting	Fossil	Various	Bronze	Walking, cycling and car	CO_2emissiefactoren.nl

BIER 2012: Research on the Carbon Footprint of Beer - Beverage Industry Environmental Roundtable, June 2012

3

Insights

Definitions used

Green House Gas Protocol

In this report emissions are presented in kg CO_2e in accordance with the Greenhouse Gas (GHG) Protocol Corporate Standard (2001). This provides a framework for GHG accounting that is divided into 3 scopes:

- scope 1: direct emissions
- scope 2: indirect emissions from electricity and
- scope 3: other indirect emissions.

Methodology

Based on the components supplied, the CO_2e footprint was calculated for each scope, on the basis of the available emission factors. These emissions were then allocated to the various production batches and periods (months).

Key Performance Indicators (KPIs)

The KPIs calculated include the total emissions, the emissions per production unit (hl), the emissions per component and per scope, and the possible future CO_2e levy. The emissions per product were then calculated per production unit and per period. In addition, the emissions per period (months) were calculated in relation to production units and the average outdoor temperature per month.

Origin of the carbon

Against the background of the envisaged circular carbon economy, the origin of the carbon was accounted for by category of origin (4 categories: fossil, biomass, recycled and CO_2 source).

Data completeness

The data completeness indicates the extent to which the figures supplied are mutually consistent.

Recipe divergence compared with annual figures

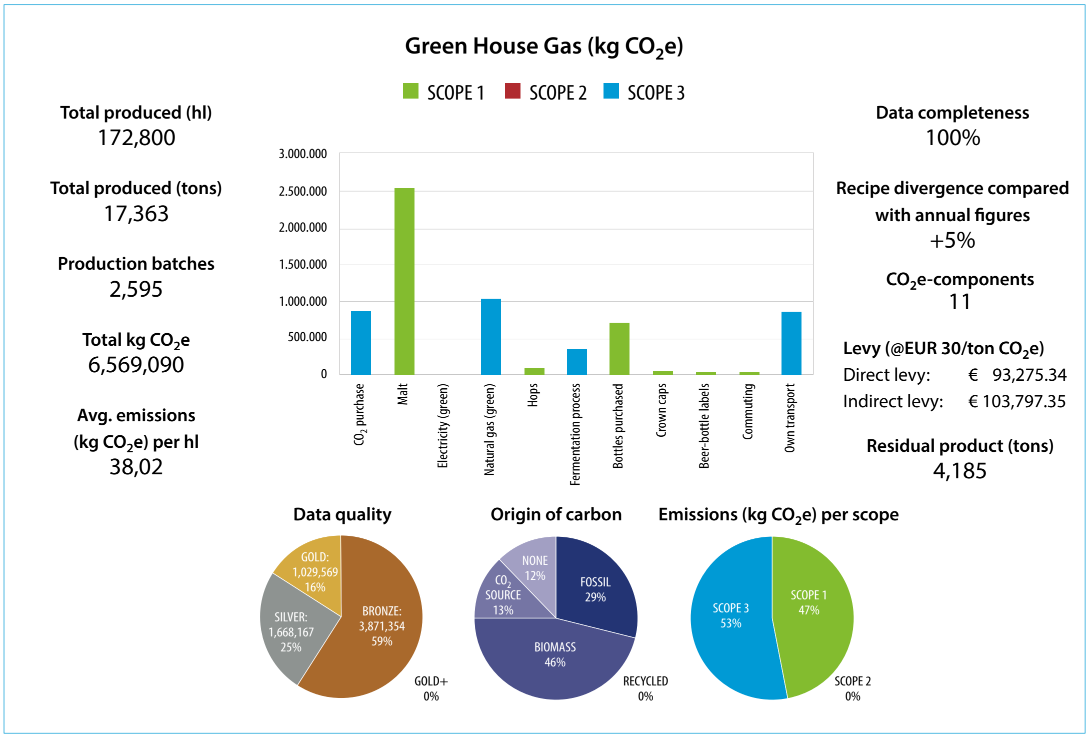
Recipe divergence compared with annual figures indicates the extent to which the production figures (based on the recipe) correspond to the purchasing figures for the raw materials.

Data quality

The data quality indicates the accuracy of the figures supplied:

- bronze: estimates;
- silver: measured annual figures;
- gold: measured monthly figures;
- gold plus: measured monthly figures for each production phase).

Management summary



Production

The above management summary first shows the total number of hectoliters of beer produced in the top-left corner (including the conversion to weight) and the number of production batches over the twelve-month production period.

Emissions

The total CO_2e emissions have also been calculated using the emission factors and the average emissions per hectoliter of beer. The bar chart (top center) shows the eleven components on the basis of CO_2e emissions and GHG scope. The number of CO_2e components corresponds to the number of components shown in the bar chart.

Data quality

Data quality shows the assurance categories of the components expressed as a percentage of total CO_2e emissions.

Origin of carbon

Origin of carbon shows the origin of the components expressed as a percentage of total CO_2e emissions.

Data completeness

Data completeness indicates the extent to which the data are complete over the entire period.

Recipe divergence compared with annual figures

Recipe divergence compared with annual figures indicates the extent to which the production figures (based on the recipe) correspond to the purchasing figures for the raw materials.

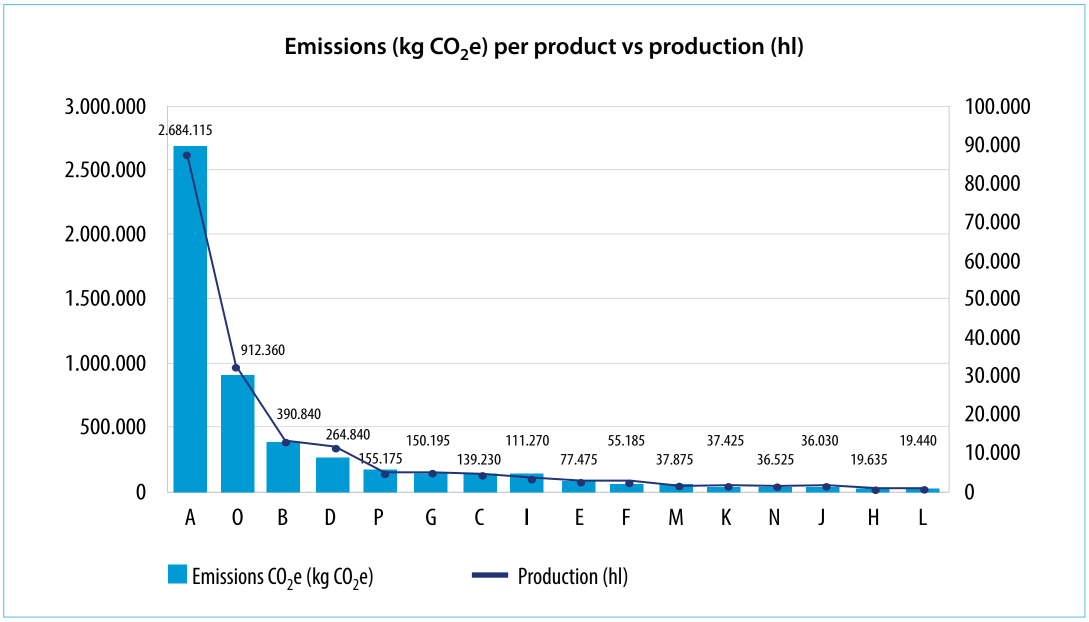
Levies

The levies have been divided into direct and indirect levies. Direct levies relate to GHG scopes 1 and 2 (direct emissions and indirect emissions from electricity consumption) and are charged directly. Indirect levies relate to scope 3 and will be paid by suppliers.

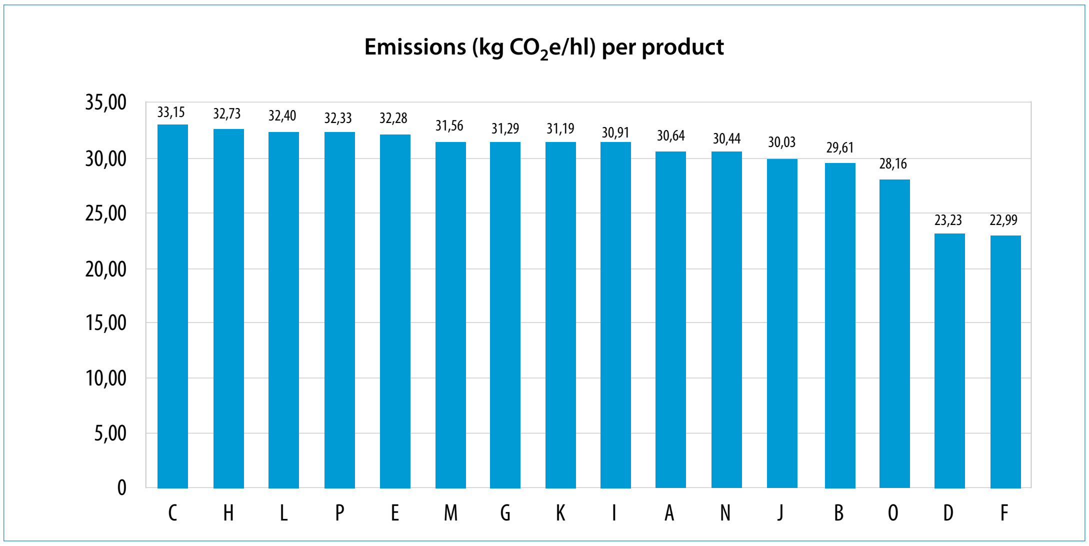
Residual product

The residual product indicator shows the weight of residual product that is sold to third parties as a by-product. In this case this is draff (spent grain), which is sold as feed to livestock farmers. In this calculation all CO_2e is allocated to the end products (beer). No CO_2e is allocated to the residual product here.

Emissions per product

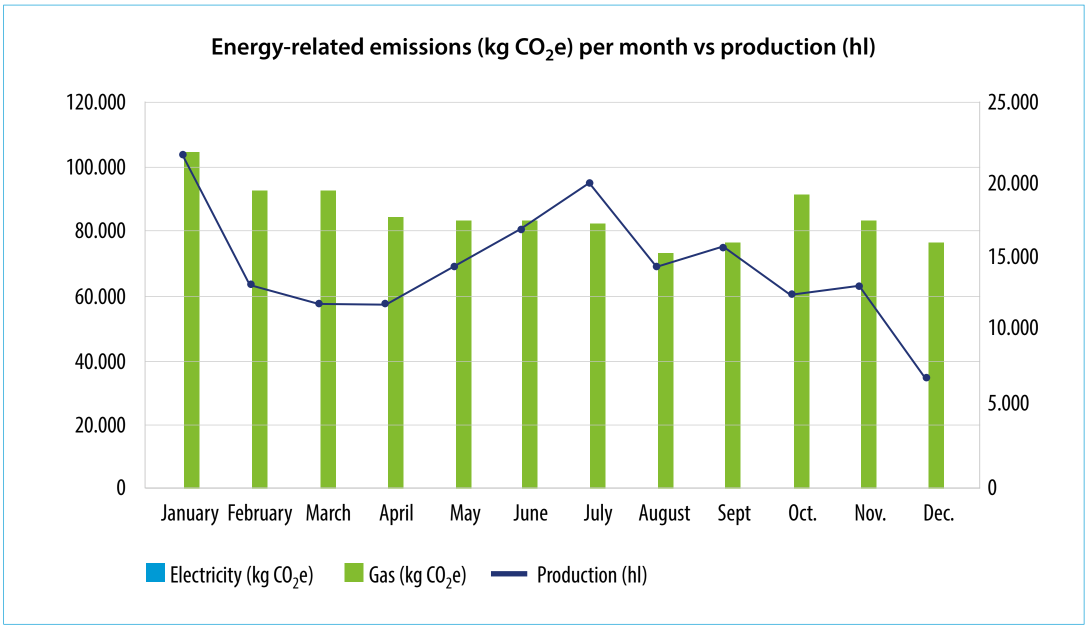


The emissions per product show the total CO_2e emissions for each beer product on the primary axis (left). The secondary axis (right) shows the total production for each beer product in hectoliters.

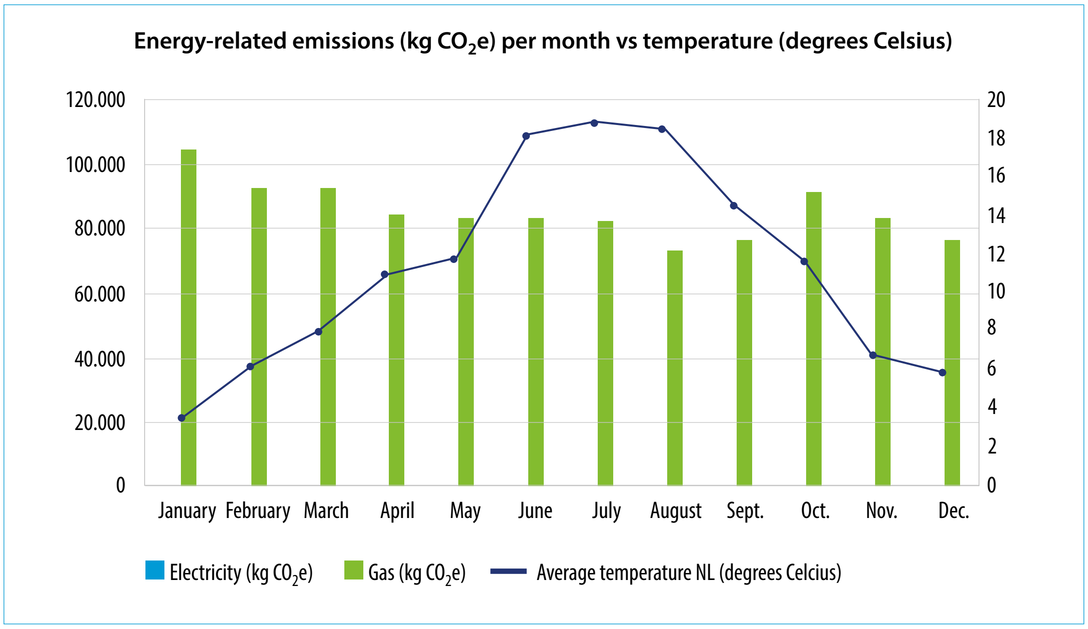


The above bar chart shows the emissions (in CO_2e) per production unit (hl) per product.

Energy consumption per month



The primary axis (left) of the above graph shows the energy-related emissions for the components 'electricity' and 'gas' per month in relation to the production on the secondary axis (right).



The primary axis (left) of the above graph shows the energy-related emissions for the components 'electricity' and 'gas' per month in relation to the average outdoor air temperature in the Netherlands for the same month on the secondary axis (right).

Insights gained

The management summary first presents the production data for the entire period (in this case a whole calendar year). The producer can therefore see at a glance whether the totals (including residual product) tally with the annual figures. In addition, the total emissions are shown (both the total and the average per production unit) and have been broken down clearly on the basis of the three GHG scopes, with the emphasis placed on the components and scopes that generate the most emissions.

The direct and indirect levies have also been calculated on the basis of the (indicated) assumed price in euros per ton of CO_2e. This provides an indication of what the additional costs will be if the assumed price is declared applicable.

For the purposes of the desired carbon accounting, the emissions are broken down into categories based on the origin of the carbon. An insight into the impact of the components in terms of greenhouse gas emissions can therefore be gained at a glance.

The divergence between components consumed in accordance with the recipe, on the one hand, and the annual figures, on the other, is an indication of the relationship between purchased components - which result in the CO_2e emissions shown over the period - and their consumption during the production process - which forms the basis for allocating these emissions to the various products. The lower the absolute percentage, the closer together purchasing and consumption are over the period.

Data completeness indicates the extent to which the data are complete over the entire period, e.g. whether all energy bills and production batches are complete for the entire period and tally with the annual figures. Data quality shows the assurance categories of the components expressed as a percentage of total CO_2e emissions. This provides an insight into the extent to which the results shown are based on detailed data and the extent to which the data quality can be improved.

In concrete terms the calculations indicate:

1. What the producer's total CO_2e emissions are, what levies result from them and how these emissions can be broken down (in terms of components and GHG scope);
2. What the CO_2e emissions are per product produced;
3. What the CO_2e emissions are per production unit per product;
4. How the energy-related emissions per month relate to the production and the average outdoor temperature in that month.

This provides an insight into where the greatest gains can be made if actual emission reductions are achieved by means of additional measures. The producer can also easily determine the CO_2e emissions that are generated per bottle or barrel of any type of beer and use this information for benchmarking or marketing purposes.

4 Conclusions

This study demonstrates that, with the data a producer has available, it is possible to perform an actual, concrete carbon footprint calculation using standard spreadsheet software. By maintaining a clear distinction between the GHG scopes and the different assurance categories (in particular in GHG scope 3), we can obtain reliable figures that can be used to reduce the footprint, perform benchmarking and participate in supply chain accounting.

The carbon footprint calculation performed reveals the main key performance indicators, such as:

1. What the producer's total CO_2e emissions are, what levies result from them and how these emissions can be broken down (in terms of components and GHG scope);
2. What the CO_2e emissions are per product produced;
3. What the CO_2e emissions are per production unit per product;
4. How the energy-related emissions per month relate to the production and the average outdoor temperature in that month;

This provides an insight into where the greatest gains can be made if actual emission reductions are achieved by means of additional measures. The producer can also easily determine the CO_2e emissions that are generated per bottle or barrel of any type of beer and use this information for benchmarking or marketing purposes.

The figures and graphs presented give rise to questions such as:

- Is it possible to adapt malt purchasing (GHG scope 3) in such a way that lower CO_2e emissions can be achieved?
- Is it possible to reduce consumption of natural gas by increasing the use of (green) electricity?
- Is it possible to reduce consumption of natural gas and electricity by partially shutting down the production site in months with a limited number of production batches?
- What gains can be made in relation to the transport of end products to customers (e.g. use of electric transport or more efficient transport by third parties)?
- Can the consumption of carbon dioxide gas be reduced by using more CO_2e-friendly variants (without affecting the taste of the beer)?
- What are the impacts on emissions if carbon dioxide is captured (e.g. fermentation process) and at what level of CO_2e levy does this become financially attractive?
- What is the impact on total costs of varying levies?
- What benefits could be achieved in the area of emissions if the production volumes of each beer product were changed (bear in mind the Jevons paradox[6])?
- How do the emissions of the beer products produced relate to one another and to benchmarks (and can lessons be learned or a marketing advantage gained from this)?

6 *In economics the Jevons paradox states that technological progress that increases the efficiency with which a resource is used will tend to lead to higher (rather than lower) consumption of that resource.*

The brewery case study involves numerous aspects that are universal and therefore also apply to other technical conversion processes. After all, many technical conversion processes are based on production batches with a recipe for each product. The effects of using (liquid) carbon dioxide, CO_2e emissions generated from (bio)chemical processes in production, energy consumption and emissions from purchased components, employee commuting and transport to customers are also taken into account in the case study. Many of these aspects also apply to other production processes (with or without a degree of adaptation).

By also recording the assurance categories, the end product can be assigned emission KPIs that create a foundation for supply chain accounting based on the (added) emissions in each part of the supply chain (if BigMile were to be adapted accordingly, a start could be made with such supply chain accounting relatively easily). This gives rise to supply chain accounting that is comparable with VAT accounting (based on added value).

The study demonstrates that it is indeed possible to develop a case study from the manufacturing industry using standard software resources. This was based solely on the data that the producer already had at its disposal and made available to us. By opting for a generic design incorporating components (broken down on the basis of GHG scope), production batches, recipes, energy bills and other public sources (e.g. outdoor temperature), an initial basis has actually been created for a concrete conceptual framework.

5 Discussion

This study raised a number of discussion points, which will be dealt with briefly in this chapter.

It became apparent that there were no clear sources of emission factors for raw materials and semi-finished products in technical conversion processes. Consequently, various sources were relied on, although it was not always clear to what extent the emission factors they contained were reliable. This gave rise to the idea of also assigning assurance categories to the emission factors, which meant that this uncertainty was appropriately addressed. The calculations in this study have not yet taken these into account.

In this study all CO_2e emissions were allocated to produced beer. Given that a significant amount of residual product is obtained - which is made available to livestock farmers in return for payment - the question is whether a portion of the emissions should also be allocated to the residual product. If this question is answered in the affirmative, this immediately leads to the follow-up question of what the basis should be for such an allocation. If a portion of the emissions were to be allocated to residual products, this may result in a need to convert 'waste' into residual products to reduce the emissions of the principal products. A discussion also arose regarding whether returned goods should be regarded as residual products.

Partly due to an absence of data, this initial study did not yet take possible changeover times before and cleaning after production batches into account. It is recommended that future case studies consider these aspects, as this would refine the figures calculated and ensure that the impacts of consecutive production batches with the same recipe (i.e. product) are incorporated into the calculations.

It is apparent from energy bills that electricity and gas consumption vary significantly from one month to another. This will naturally be influenced by the number of production batches in any month, but also by external factors, such as the outdoor temperature (gas for heating and electricity for cooling). Both of these variables were therefore taken into account. This gives rise to a discussion about which other variables could play a role (e.g. natural light, the interaction between electricity consumption and gas consumption, etc.). A number of regression calculations were also performed to look into the possibilities of examining interactions, including endogeneity, on the basis of hypotheses. Although the regression calculations are not included in this report, the initial results were sufficiently interesting to merit further elaboration. After all, the calculations could predict which variables have an impact on both electricity and gas consumption and to what extent. This would provide an additional insight into the modeling of and the potential for improvement in relation to CO_2e emissions.

As emissions are determined on the basis of purchased components and allocated on the basis of production batches and recipes, discrepancies can arise when different periods are compared. After all, if substantial stocks are built up in year n for subsequent years, year n will show high emissions and the following years low emissions. In this study this problem was addressed by means of the indicator 'Recipe divergence compared with annual figures', which revealed that there was little (+5%) divergence between the recipe and the annual figures. The question is how this should be handled if this percentage is (significantly) higher.

In this report the origin of the carbon has been incorporated into the calculations. However, the question is to what extent this will remain relevant if reliable emission factors are available for the various components. After all, the emissions of the different GHG scopes could then be calculated, which would mean a higher level of accuracy would be achieved compared with calculations based on categorization of the origin of the carbon.

Connekt/Topsector Logistiek
Ezelsveldlaan 59
2611 RV Delft
+31 15 251 65 65
info@connekt.nl
www.connekt.nl

Topsector Logistiek