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Analyses of carbon footprint in the import process for wine

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Abstract: *Purpose*: This study investigates whether wines imported from the New World generate higher carbon emissions per 0.75L bottle during distribution to Germany than Old World wines and identifies key factors influencing the carbon footprint (CF) in the distribution process.

Methodology: The research analyses a large dataset (over 220,000 records) from a primary European logistics provider, applying the EN 16258 standard and EcoTransIT World (ETW) tool to calculate CO2 equivalents for various distribution channels, shipment sizes, and modes of transport. Simulations for New World shipments complement empirical data.

Results: Distribution channel, shipment size, and logistics handling significantly influence CF per bottle. Large, direct shipments to retailers have lower CF than small, multi-stop shipments. Contrary to common assumptions, New World wines do not always have a higher CF than Old World wines; logistics networks and shipment handling are critical determinants.

Theoretical Contribution: This paper extends the literature by empirically quantifying the impact of logistics variables on wine CF, challenging the generalisation that New World imports are inherently less sustainable.

Practical Implications: Findings inform wine importers, retailers, and policymakers on optimising logistics for lower emissions and provide a nuanced basis for consumer sustainability choices.

Keywords: carbon footprint, wine distribution, logistics, greenhouse gas emissions, supply chain, sustainable transport

Sustainable Development Goals (SDGs): SDG 7: Affordable and Clean Energy; **SDG 9:** Industry, Innovation and Infrastructure; **SDG 11:** Sustainable Cities and Communities; **SDG 12:** Responsible Consumption and Production; **SDG 13:** Climate Action

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1. Introduction

Customers' changing preferences and needs mean that food has to be imported. Not all food requirements can be produced locally, as certain products are not manufactured in Germany.

This also applies to wine. In addition to wine from Germany, wine is imported from many regions outside Germany. In addition to the larger wine-growing regions such as Italy, France, Spain and Austria, this also includes wines from overseas or the New World, such as South Africa, the USA, Australia and Chile. The "well-established" countries have an import share of 80%, whereas the countries of the New World "only" have a share of just under 15% if Argentina and New Zealand are also included (see Table 1).

Table 1: Important countries of origin for wine into Germany by import volume 2022

Country	Year	%
	2022	
Italy	4,859	36.3%
Spain	3,681	27.5%
France	1,779	13.3%
South Africa	649	4.8%
USA	405	3.0%
Australia	400	3.0%
Austria	395	2.9%
Chile	331	2.5%
North Macedonia	204	1.5%
Hungary	190	1.4%
Portugal	170	1.3%
New Zealand	91	0.7%
Argentina	71	0.5%

Source: (German Wine Institute, 2023, p. 27)

The market share of purchased German wines has fallen to 44% (cf. German Wine Institute, 2023, p. 2). As a result, 56% of wine is imported. The proportion of New World wines is significantly higher in other European markets such as the UK. In 2011, these wines had a share there of 48.7%. (Amienyo, Camilleri, & Azapagic, 2014)

The wine industry is a significant source of greenhouse gas emissions. Between 0.5 and 2.9 kg of CO2 equivalents (CO2e) are emitted per 0.75 litres of wine, with the average for German wine ex works (excluding outgoing logistics) being 0.83 kg CO2e. It should be noted that there is a wide range from 0.2 to 2.9 kg CO2e due to the many ways in which wine can be produced and packaged. (D'Ammaro, et al., 2021) / (Ponstein, Meyer-Aurich, & Prochnow, 2018) / (Navarro, Puig, Kilic, & Penavayre, 2017) / (Marco-Fondevila, Moneva, & Llena-Macarulla, 2020) Other studies even analysed a mean value of 2.2 kg for a 0.75 L bottle. They presented a potential for reduction using organic cultivation (Rugani, Vazquez-Rowe, Benedetto, & Benetto, 2013).

The existing studies have focused on calculating CO2 within the vineyard and the wine cellar, i.e., from the grape to the dispatch gate. Further distribution has only been examined in detail in a few studies. (Ponstein, Ghinoi, & Steiner, 2019) (Navarro, Puig, & Fullna-i-Palmer, 2017) (Amienyo, Camilleri, & Azapagic, 2014). Many studies refer to countries such as Spain, Italy, France, Portugal, and the USA (Ponstein, Meyer-Aurich, & Prochnow, 2018) and the German market. In most cases, these were simplified assumptions about tkm and the direct distance calculation or other average distances (Ponstein, Ghinoi, & Steiner, 2019) (Point, Tyedmers, & Naugler, 2012) (Gazuella, Raugei, & Fullana-i-Pallmer, 2010) (Bosco, et al., 2011) (Neto, Dias, & Machado, 2013) (Amienyo, Camilleri, & Azapagic, 2014). Or other average assumptions were made about capacity utilisation and vehicle type (D'Ammaro, et al., 2021).

A direct investigation of how the wine gets from the winemaker to the point of sale using a logistics service provider was not found. Nevertheless, it is estimated that the contribution of wine to global anthropogenic greenhouse gas emissions is about 0.3% of annual global GHG emissions (Rugani, Vazquez-Rowe, Benedetto, & Benetto, 2013).

Amienyo et al. (2014) demonstrated the importance of the wine sector at a national level for a country with high per capita wine consumption and estimated that annual wine consumption in the UK accounted for 0.6% of national GHG emissions. This shows that even if the wine industry is strongly affected by climate change, it is also a relevant driver of global warming. (Cf. Prochow, Meyer-Aurich, & Prochnow, 2018, p. 801)

As sustainability or CO2 emissions are becoming an increasingly important criterion for consumers' purchasing decisions (Navarro, Puig, Kilic, & Penavayre, 2017), this study aims to investigate whether wines from the New World generate higher CO2 emissions per 0.75-litre bottle of wine in terms of distribution than wines from the Old World and to analyse the determining factors that influence the carbon footprint (CF) in the distribution process.

2. Literature review

Existing CO2 calculation results

The greenhouse effect is calculated in CO2, despite knowing that this effect is determined by other influencing factors such as methane (CH4) and nitrous oxide (N2O). The literature, therefore, often refers to CO2 equivalents and includes the components accordingly. The unit is then expressed as CO2e (Bosco, et al., 2011). The term carbon footprint (CF) is also often used in simplified form (D'Ammaro, et al., 2021).

The existing studies calculating CO2 or CO2e have shown that the most significant driver of greenhouse gas emissions is the glass bottle and that reducing the weight of the bottle, the type of packaging (BIB), or a possible deposit system on the bottle offers opportunities to reduce CO2 (Ponstein, Meyer-Aurich, & Prochnow, 2018) (Navarro, Puig, Kilic, & Penavayre, 2017).

This study focuses on the distribution of wine from the winegrower to the point of sale (POS). For this distribution process, the CO2 emissions of the shipments are to be analysed.

Most wines are distributed via the retail trade (German Wine Institute, 2023) p. 34). Shipments to the "catering trade", such as hotels or restaurants, are only partially included in this figure, as caterers are also supplied via special distributors or wholesalers.

Table 2: Distribution channels for wine in Germany

Discounter	38%
Retail chain	28%
Winery direct	9%
Beverage market	5%
Specialised wine retailer	5%
Online retailer	5%
Winery online	4%
Others online	2%
Others	4%

Source: (German Wine Institute, 2023) p. 34

System boundaries

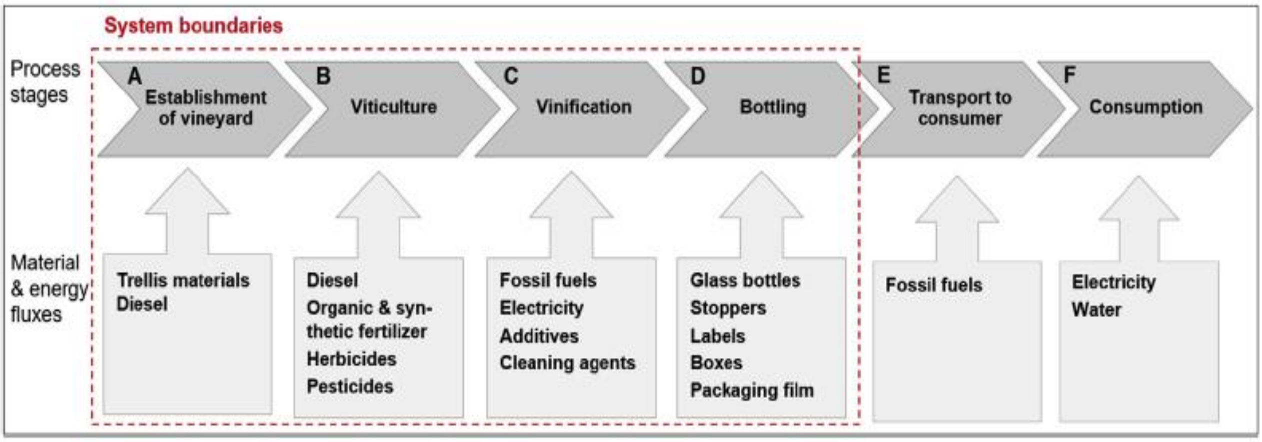
A distinction is made between the following six process steps regarding CO2 emissions from wine production to consumption (see Illustration 1). This represents the life cycle and is referred to as Life Cycle Assessment (LCA) (Blass & Corbett, 2017).

Other authors divide the process into only four phases and do not consider phases A and F separately (Merli, Preziosi, & Acampora, 2018). Others extend the life cycle or the system boundaries and integrate waste disposal (waste management) or customer transport into the POS as well as cooling in the household (Point, Tyedmers, & Naugler, 2012) (D'Ammaro, et al., 2021), so-called "end of life processes". (Rugani, Vazquez-Rowe, Benedetto, & Benetto, 2013). In addition to possible differences in wine processing and vinification (processes, size of the vineyard, grapes, organic versus conventional processing, use of yeast, ageing, etc.), these different considerations and allocations to the LCA of the wine can also be used as a basis for the LCA of the wine (Vazquez-Rowe, Rugani, & Benetto, 2013) (Steenwerth, Strong, Greenhut, Williams, & Kendall, 2015) (Russo, Strever, & Ponstein, 2021). This may be the reason why the calculated CF values in various studies have a relatively large deviation (Scrucca, et al., 2020).

The analysis in this article refers to the distribution of the LCA labelled "E" in the illustration. In other words, from the winemaker's ramp to the point of sale.

Looking at the factors influencing the winery, the distribution of the wine to the POS is more likely to be categorised as other indirect emissions (see Illustration 2). Analysing the SCOPE 1, 2 or 3 influences within a product's LCA can produce very different results. This can lead to only 22% being attributed to the upstream or procurement phase in the supply chain instead of 74% (Blass & Corbett, 2017).

Illustration 1: System boundaries of CF-relevant processes in the wine life cycle



Source: (Ponstein, Ghinoi, & Steiner, 2019), p. 802

Regarding the process steps in viticulture and wine production, the most important factors besides the glass bottle are the electricity used, the heat produced during vinification, and the diesel consumed for processing (Ponstein, Ghinoi, & Steiner, 2019).

Illustration 2: CO2e for wine production

Viticulture stage	Winery stage
Scope 1 – direct emission sources	
Diesel use by tractor (L)	Diesel and gasoline used in vehicles (L)
N_2O from fertilizer applications (kg N-fertilizer)	Heat production, natural gas and heating oil (kWh)
CO_2 from liming (kg $CaCO_3$)	Fugitive emissions from losses of cooling agents (kg)
Scope 2 – indirect emission sources	
n.a.	Electricity (kWh)
Scope 3 – other indirect emission sources	
Trellis system material[a] (kg) and lifespan (years)	Additives and cleaning agents (kg)
Production of fertilizer (kg synthetic N, P_2O_5, K_2O)	Reusable and single use glass bottles (0.75 L, 1.0 L) (kg)
Production of phytosanitory products (kg)	Labels and stoppers (kg)
Commuting of staff (pkm[b])	Secondary packaging (boxes, foil) (kg)
	Provision of fossil fuels (kWh, L)
	Commuting of staff (pkm)

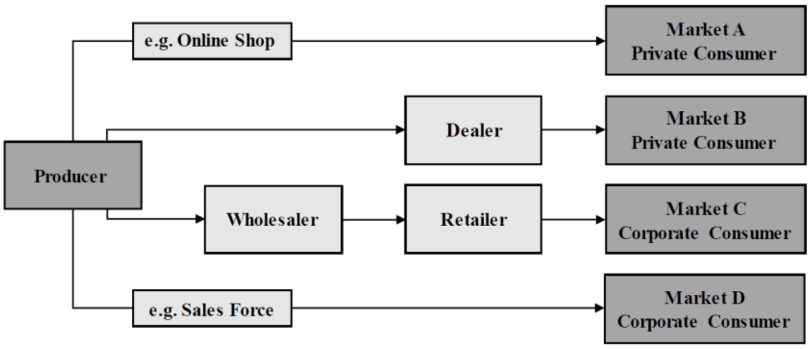
Source: Own representation based on (Ponstein, Ghinoi, & Steiner, 2019), p. 777.

CO2 emissions can be calculated directly based on consumption. In this case, the energy consumption of the mode of transport to cover the distance must be known. This direct determination of fuel consumption is not always possible, as external transport service providers often carry out transport. Therefore, the transport energy consumption for each consignment is challenging to determine. An alternative would be to use the average consumption of a comparable transport or the average consumption of the logistics service provider's fleet ((DSLV), 2013), p. 38ff.

Another option is to use the distance-based method, considering the influencing factors of a means of transport and specifying default values. In road freight transport, for example, these are the truck type, the weight, the load factor, the empty kilometres, the fuel type, the distance and topography.

The exact execution of the wine consignment must, therefore, be known in order to determine the CF precisely. On the one hand, the execution of the transportation itself must be determined – in addition to the start and end point, the truck type, the capacity utilisation and the associated empty kilometres – as well as the type of delivery. This is because the consignment is handled via different logistics networks depending on the distribution channel (see Illustration 3). These distribution channels are becoming increasingly complex due to new possibilities in online distribution (Ailawadi & Farris, 2020). These are often country-specific and independent, leading to different service levels (Göbl & Niersbach, 2017).

Illustration 3: Examples of various distribution channels



Source: (Ailawadi & Farris, 2020)

The reason for choosing different logistics networks lies in different shipment sizes. For example, the shipment size of wine to a wholesaler will certainly be larger than the shipment from an online shop to a private or commercial end customer, who probably only orders the wine by the bottle or box, while deliveries to wholesalers are made in complete trucks, or to specialist retailers on pallets. A key differentiator in logistics processing is, therefore, whether we are talking about a full truckload (FTL), less than truckload (LTL), groupage shipments (1-5 pallets) or parcels. If there is a groupage or parcel shipment, its handling requires a logistics network in which the goods are collected via transhipment points and forwarded via other transhipment points.

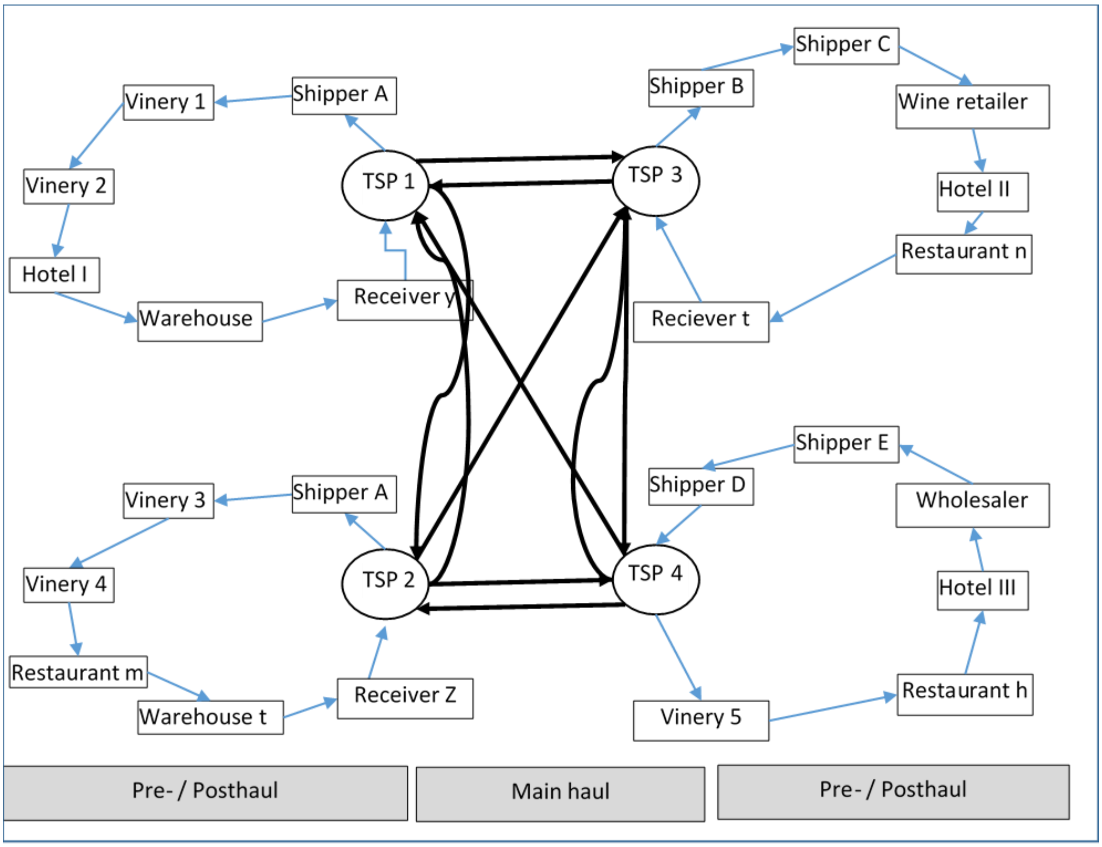
Parcel or groupage shipments are processed via a network in which the goods are collected from the various senders with a smaller single truck in the pre-haul and then usually transported to the next transhipment point with a large-volume, fully loaded truck in the main haul. From there, the consignment is then delivered to the receivers post-haul. Pre- and post-haul are usually combined, and goods are delivered to the recipient and collected from the sender simultaneously. In logistics terminology, this is referred to as short-haul transportation. In the case of wine, senders are usually winegrowers or their storage locations, retailers or co-operatives (collectively named here as warehouses). Typical recipients are wholesalers or the central warehouses of food retailers (LEH) or discounters. Goods can also be distributed to specialised distributors for restaurants and hotels or online retailers' warehouse locations. Recipients can be specialist retailers, as well as restaurants or hotels directly.

The following illustrations provide an overview of the various logistics networks used for deliveries to retailers, which are generally organised and handled by a logistics service provider. However, different types of transportation activities are required depending on their logistics networks and business locations or business partners.

This complexity is illustrated in the following figures. Illustration 4 shows a simple logistics network of a logistics service provider, indicating four transhipment points (TSP 1-4). Depending on the volume of shipments, the local transportations from each TSP are scheduled to maximise the capacity utilisation of the pick-up/delivery vehicle and ensure the route to be covered can be completed within the required time frame.

If TSP 1 is located in Italy, it makes a difference whether this location is in Verona and serves wineries in the Veneto region or whether it also supplies wineries in Tuscany from this point. The area these transhipment points cover and the number and route length of the associated local transport operations vary depending on the service provider's network.

Illustration 4: Sketch of a logistical general cargo network with direct transport



Another factor influencing the logistics network and the associated CO2e emissions is whether each TSP has collected enough goods from the consignors to make it worthwhile to drive to the other transhipment point with a utilised truck. Assuming that the transhipment point TSP 1 in Verona collects enough goods from the consignors in Italy, it would be worthwhile to transport them to TSP 3 directly. Let's assume that this is located in Vienna. In the same way as TSP 1 in Verona, the TSP 3 in Viena then plans the local transportation according to the consignments to be delivered to the recipients or collected from their consignors.

If a logistics service provider does not have enough shipments to make it worthwhile to transport directly between the transhipment points, one or more main transhipment bases (referred to as "hub-spoke", based on to a tyre with several spokes) are used (see Ill. 5). The advantage is that there is less risk of utilising the truck of the main runs. However, this network leads to longer transport distances and a longer transit time due to an additional transhipment.

However, if the logistics service provider has enough transport volume for a recipient in the Vienna area (e.g. a food wholesaler in the vicinity who orders one truck with northern Italian wines), the goods would be transported directly (see Ill. 6).

Illustration 5: Representation of a general cargo network utilising a HUP

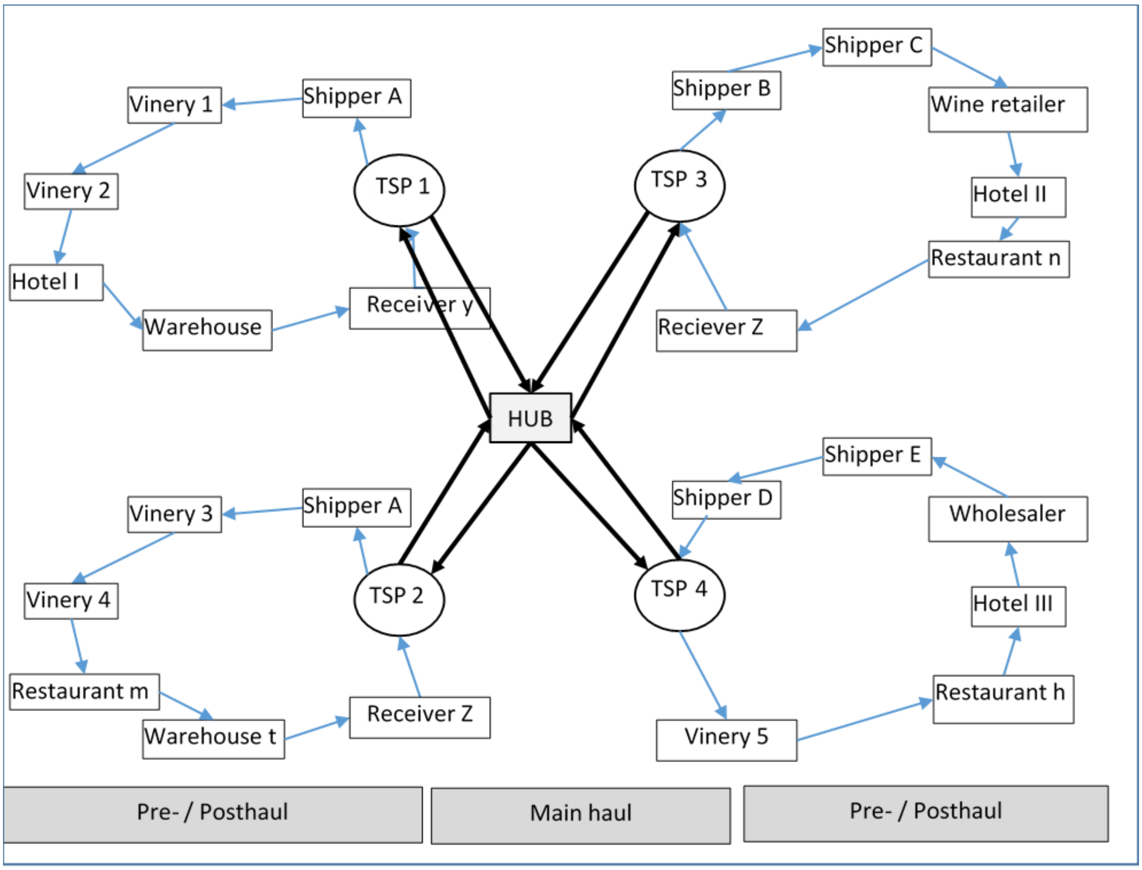
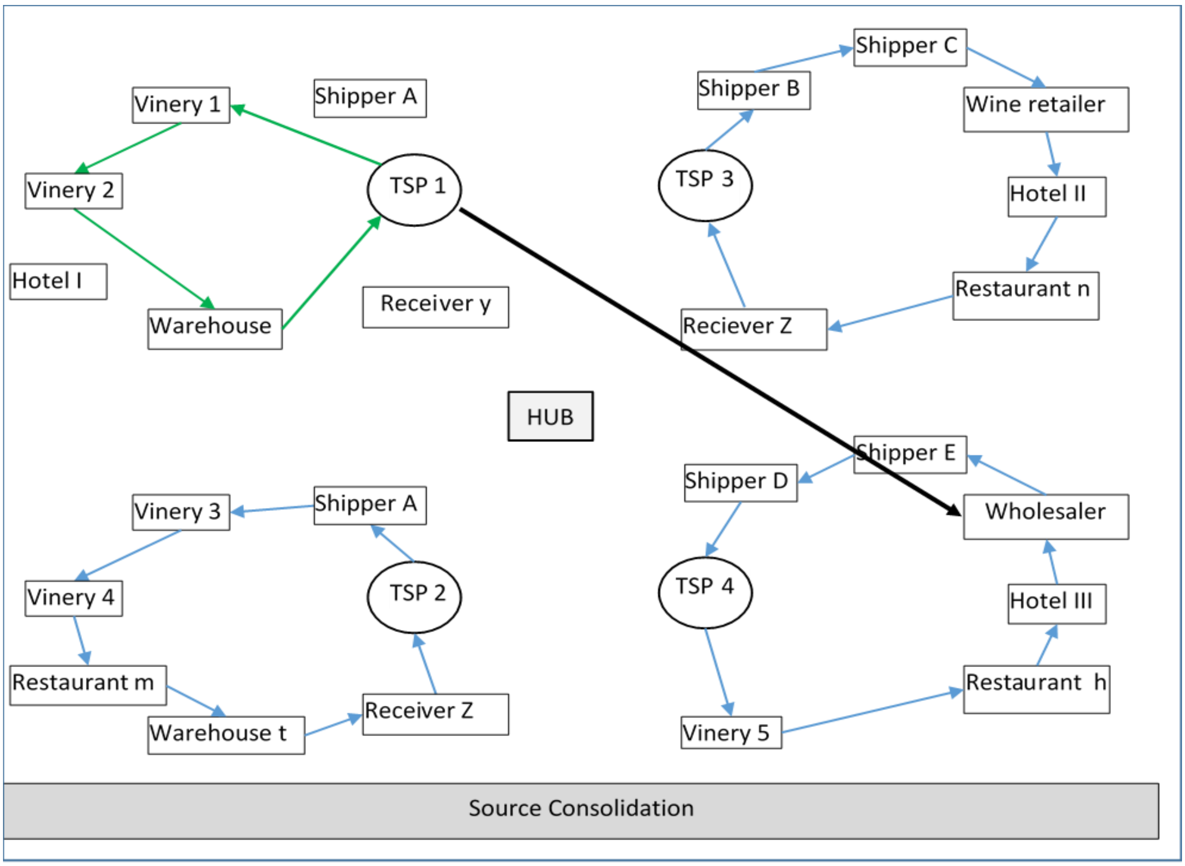


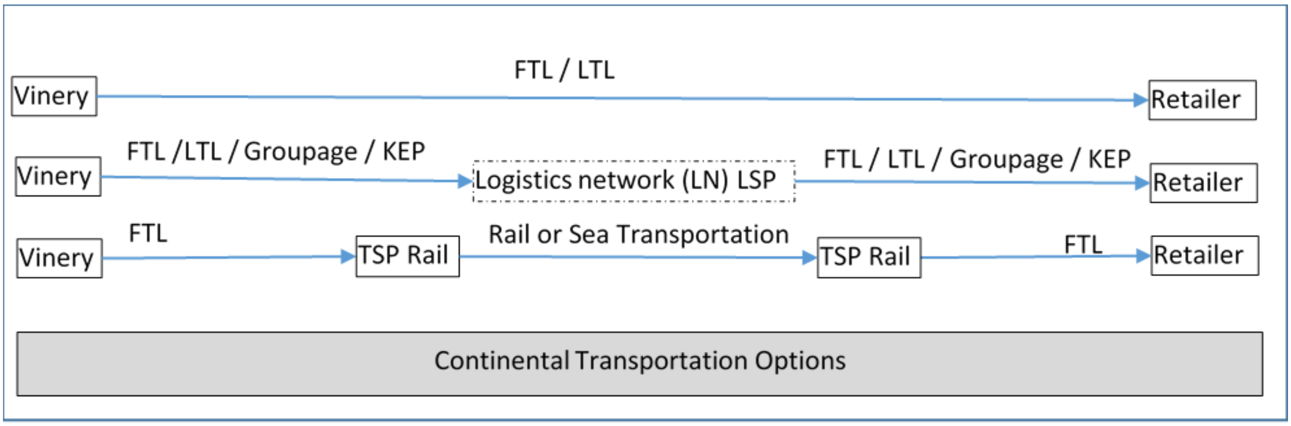
Illustration 6: General cargo network with direct delivery



Another important factor influencing the CO2e emissions generated by transport operations is the mode of transport used. For example, a truck with a payload of twelve tonnes is more likely to be chosen for local transportation, while trucks with two swap bodies or articulated lorries are more likely to be used for the main leg.

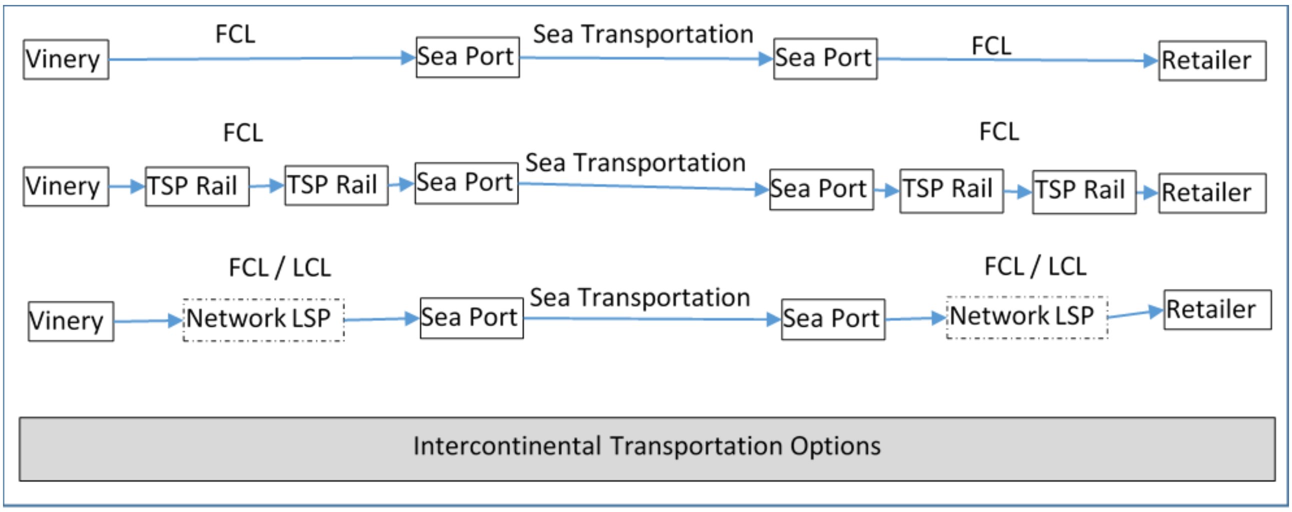
Intermodal transportation is also often interesting if the main journey has to be made over longer distances and rail routes or waterways are available. The main journey can then be carried out in a more climate-friendly way by rail or ship. (See the three illustrations in Ill. 7).

Illustration 7: Options for carrying out the main run in a logistics network



This type of handling is quite similar to transportation between continents. Wine from the New World is first transported to a port in the country of departure, e.g. Valparaiso for Chile or Cape Town for South Africa, and then transported by container ship to the destination area. As this study looks at Germany as the destination country, mainland Europe will receive ports, either the western ports (Rotterdam, Amsterdam, Antwerp) or the northern ports (Hamburg, Bremerhaven, Wilhelmshaven). If the sending or receiving location is far from the port, most of the route can also be covered by rail or inland waterway. However, even in intercontinental transportation, the containers are not always guaranteed to be complete (full container load FCL). It is also possible to consolidate smaller shipment volumes via a logistics network (see above). This is referred to analogously as "Less than Container Load" (LCL). The deconsolidation of bundled small shipments can also take place in the receiving area, where shipments are delivered to different recipients in one container via a corresponding logistics network.

Illustration 8: Intercontinental transportation processing



3. Research questions & methods

In order to be able to analyse the exact CF impact of distribution in the context of the LCA of wine, it is necessary to know how the shipment was transported from the winery to the point of sale. As the networks managed by the various logistics service providers are different, a statement can only be made by analysing wine shipments from the past.

Existing data for the wine distribution by a logistics service provider are used for this study, in which the wine was transported in pre-filled glass bottles. Therefore, possible savings effects through bulk goods and subsequent bottling close to the POS were not analysed. Reference is made here to studies by Amieyo or Ponstein (Amienyo, Camilleri, & Azapagic, 2014), (Ponstein, Ghinoi, & Steiner, 2019).

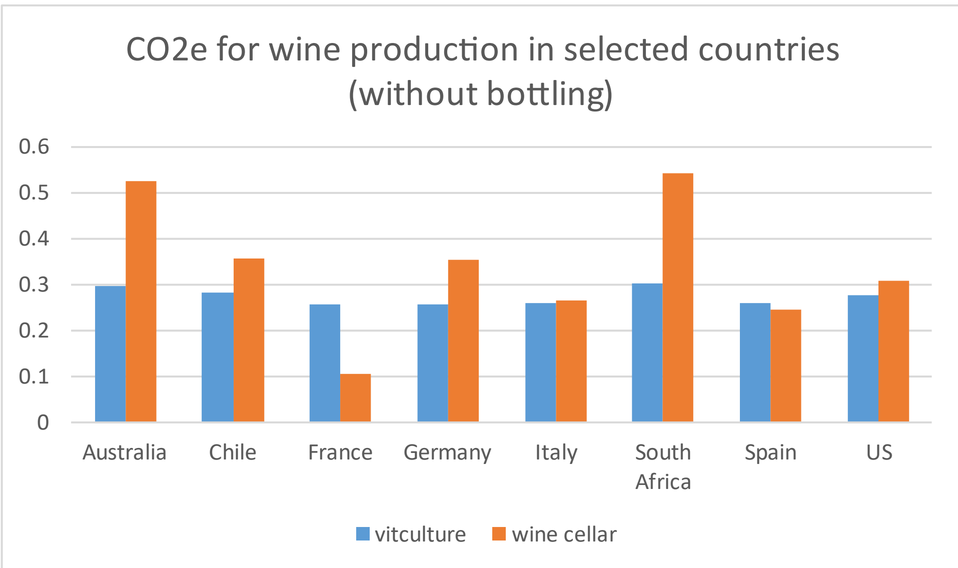
How the customer reaches the POS has been excluded. The majority (68%) of wine in Germany is sold via food retailers and discounters (see Fig. 1).

The CO2 emissions are determined for the entire transportation and divided proportionally between the consignments.

This study did not include potential differences between wine production in the countries due to the local composition of electricity (share of green electricity) (Ponstein, Ghinoi, & Steiner, 2019) or share of irrigation.

However, if you compare the pure CO2e consumption for wine production (i.e. viticulture and the work in the wine cellar) without bottling, you can see that the differences are insignificant. Only the CO2e values in viticulture from Australia, France and South Africa deviate by approx. 200g from the mean value, as the CO2e consumption for electricity production was assessed to be significantly higher. (Ponstein, Ghinoi, & Steiner, 2019). This is astonishing, considering that the countries of the New World are described as pioneers of sustainability in wineries (Merli, Preziosi, & Acampora, 2018), (Szolnoki, 2013).

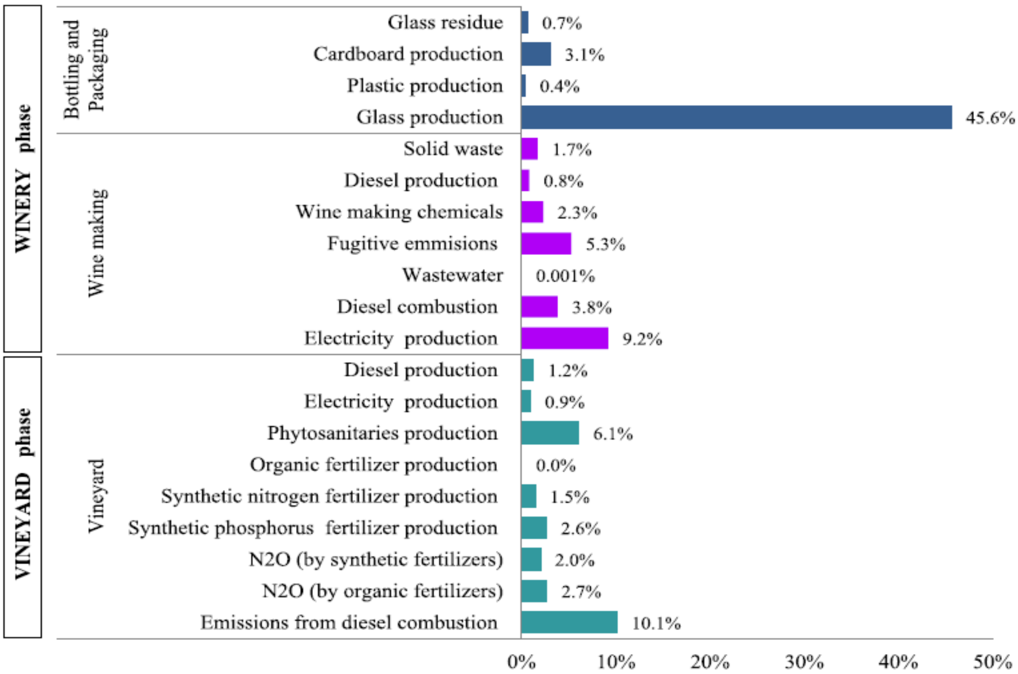
Figure 1: CO2e values for wine production in selected countries



Packaging in glass bottles would then cause approximately the same CO2e emissions. The following figure shows the proportion of factors influencing the process steps up to the provision of the bottle of wine (see Fig. 2).

Those studies that have included the distribution process in the CF calculation publish proportional values for distribution ranging from 2% to 41% (D'Ammaro, et al., 2021). This high deviation shows that the distribution process has only been modelled in a very simplified way in the existing literature on the CF calculation for wines.

Figure 2: Proportional CO2 emissions in wine production



Sourve: (Navarro, Puig, Kilic, & Penavayre, 2017), p. 1668

This study focuses on distribution from the winery to the corresponding points of sale.

In order to find out how the wine shipment got from the winegrower to the respective POS, real shipment data must be analysed, as there are many different ways in which the shipment is organised. The physical transportation of the shipment does not necessarily have to be carried out by the logistics service provider itself but possibly another freight forwarder (Göbl, 2009). Nevertheless, it is organised and controlled by the logistics service provider, which means that the data required to determine the CO2e for the shipment is readily available.

The following hypotheses are to be verified in this thesis:

H1: The CO2 emissions for a wine consignment differ according to the various distribution channels. The reason for this assumption is that it is assumed that goods are usually transported directly to food retailers or discounters in full loads from the wine producer, as these customers buy large quantities correspondingly.

H2: It is also assumed that southern European wines have lower CO2e values in southern Germany than in northern Germany .

H3: The logistical handling could mean large consignments of more than 10 tonnes have lower CO2e values than small consignments due to higher utilisation of the loading container .

H4: Further evidence of the influence of logistics processing should be obtained by analysing whether direct deliveries (see Ill. 6) have a lower average CO2e value per bottle than if the shipment is processed via further onward carriage (see Figs. 4 and 5).

H5: The fifth hypothesis to be analysed in this paper is that wine from the New World does not have higher CO2e emissions than others from southern Europe.

4. Results

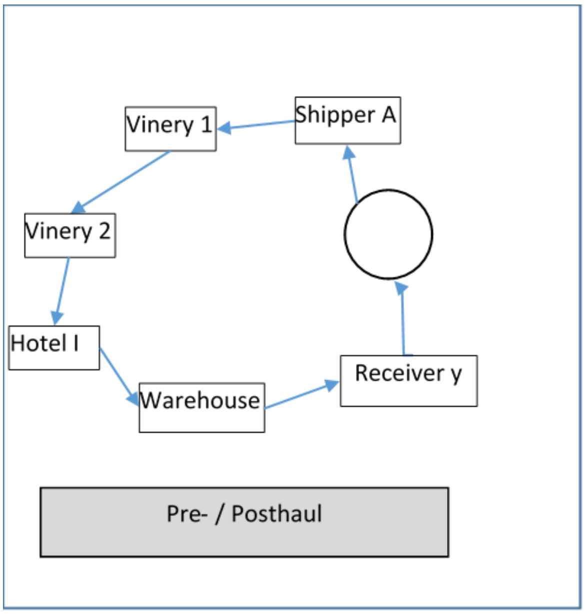
As already described, there are different ways of calculating transportation services' energy consumption and greenhouse gas emissions. To this end, the European Committee for Standardisation has developed a new standard, EN 16258 ((DSLV), 2013), which forms the basis for the calculations in this study. All results presented refer to the “well-to-wheel” calculation, considering not only the pure greenhouse gas emissions of transportation but also the provision of the fuel. This differs according to the use of diesel, petrol, biodiesel, heavy fuel oil and electricity. ((DSLV), 2013). It is possible to calculate the CF for a transport operation if the fuel consumption of the truck used for the transport route is known. If not, this is determined via the distance, the lorry type (lorry type, payload, pollutant class) and the topography. This calculation must be made separately for each transport leg and later summarised.

The challenge in conducting the calculation, however, lies in the allocation of the transport shipment, i.e. how well the mode of transport was utilised overall and what share the corresponding wine shipment had. This data must be known to determine the corresponding energy consumption or, more specifically, the GHG emissions of a wine shipment.

The calculation for sea freight or rail freight is similar. It is important to know the parameters of the load carrier used to transport the shipment that is relevant to energy consumption (ship type, distance, fuel, capacity utilisation).

Another challenge arises in the local transportation during pre- or posthaul carriage (see Ill. 9).

Illustration 9: Possible pre- or post-carriage in a general cargo transportation



Some assumptions must be made here to distribute the proportional CF of the shipment as fairly as possible. The direct route from the transhipment point with a pallet to Hotel 1 would be shorter and result in fewer CO2e emissions than if the lorry picks up or delivers shipments to Shipper A and Winery 1 and 2 beforehand. Therefore, the proportionate greenhouse gas emissions depend on the scheduling and handling of the local transportation.

For a fairer allocation, the CF of the entire local transportation is therefore used and then divided according to the tonne-kilometres (weight of the shipment multiplied by the air distance) between the transhipment point and the destination/collection point. Similarly, the distribution could also be calculated according to other parameters, such as the number of shipments, stops, and weight to be transported for the receiver/collector ((DSLV), 2013), (Kranke, Schmied, & Schön, 2011).

EcoTransIT World (ETW) is a tool that considers the DIN requirements mentioned and performs the calculation accordingly. (EcoTransIT World) The ETW Calculator available on the Internet can be used by anyone to calculate the GHG of shipments or transportation. For larger companies, a professional tool is provided for processing mass data. Other tools are available, but EcoTransIT was evaluated to fit all relevant requirements (Schramm & Lehner, 2024).

The following analyses of wine shipment data are based on data from a large logistics service provider. This provider can output a CO2e value in grammes for all transportation and shipments via the ETW Calculator.

Several thousand data records were taken into account for this study. This data comes from one of Europe's largest logistics service providers, which plays a leading role in wine transportation. The data is from 2023 for all shipments for which a CO2e value was calculated using the methodology described. All data was retrieved from Spain, France, Italy, Austria, and Germany and sent to the destination country, Germany. The data set for this sample totalled 350,000 records. The CO2e value per bottle of wine was calculated for all these data records. For this purpose, the weight to be transported was divided by an average weight per bottle of 1.2 kg (450 g glass weight and 750 g wine).

In addition, many data sets for importing wine shipments from overseas were analysed to determine the correct parameters for further analyses with the ETW Calculator.

Another advantage of this approach is that the calculation methodology and processing of a shipment in the logistics network is known, so simulations can also be carried out to analyse what-if scenarios.

It can be assumed that the logistics of wine shipments are carried out similarly by other logistics service providers. However, other logistics service providers may handle more shipments via a HUB system (see Ill. 6). The capacity utilisation and the locations of the transhipment points could differ for other logistics service providers. Nonetheless, overall, it can be assumed that this data pool represents a representative sample for deriving generally valid statements for wine distribution. Furthermore, it could be assumed that the mean of the induced CO2e values per shipment is normally distributed due to the large number of data sets. This is a functional requirement for conducting different statistical tests to verify the hypotheses.

The initial analysis step involved deleting all data with incomplete information. In the second step, the partial transports were summarised according to the transportation network used to obtain the CO2e value for the complete shipment. This value was then divided by the weight of the bottles to determine the CO2e value of a bottle of wine in the respective shipment.

The data pool contained almost 220,000 data records of shipments from various countries of departure. An analysis of the average CF values per wine bottle shows that the average CO2e value per shipment to Germany differs for each production country.

Table 3: Average CO2e value per wine bottle in distribution by country of dispatch

CO2e_per_bottle per country (for shipments to Germany)			
Country	**Mean**	**N**	**Standard deviation**
AT	124.90	2,649	66.29
DE	70.32	211,455	51.74
ES	171.68	43	52.16
FR	88.23	5,497	54.29
IT	103.14	66	62.55
Total	**71.45**	**219,710**	**52.44**

Source: author's elaboration

In order to test the first hypothesis, the customers whose distribution channel could be assigned were selected. As a result, 1/3 of the shipments could not be assigned and were considered an extra channel.

Table 4: Average value of CO2e per bottle in different distribution channels

Average value of CO2e per bottle in different distribution channels			
Channel	**Mean**	**N**	**Standard deviation**
Beverage retailers	75.40	1,987	52.43
Wholesalers and retailers	72.87	2,683	53.24
Hotels	71.90	1,944	52.03
Supermarkets (food retailer)	70.50	107,375	51.22
Wine bars, gastronomy	78.56	2,380	52.23
Not classified	72.16	103,341	53.65
Total	71.45	219,710	52.44

Source: author's elaboration

The null hypothesis that the average CO2e values per bottle of wine are the same in the different distribution channels can be rejected (see Fig. 3).

Figure 3: ANOVA CO2e per bottle per distribution channel

ANOVA

CO2e_per_bottle

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	306,348.86	5	61,269.77	22.29	0.00
Within Groups	603,962,752.00	219,704	2,748.98		
Total	604,269,100.86	219,709			

The distribution of wine shipments to food retailers has a lower carbon footprint than deliveries to wine shops or restaurants.

To verify the second hypothesis, the recipients of the wine shipments were divided according to their postcode into northern (postcode 0-49999) and southern Germany (postcode 50000-99999). The mean values for this large sample (see Table 5) already suggest that the two-sided t-test used to test whether the two mean values are equal will be rejected (see Tab. 5 and Fig 4).

Table 5: Average CO2e values for wine distribution in northern and southern Germany

CO2e_per_bottle per region

Region	Mean	N	Standard deviation
North	81.57	91,211	54.36
South	64.27	128,499	49.81
Total	71.45	219,710	52.44

Figure 4: t-test statistics regarding equality of the mean values of CO2e emissions from wine shipments in northern and southern Germany

Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means			
CO2e_per_bottle	F	Sig.	t	df	Significance	
					One-Sided p	Two-Sided p
Equal variances assumed	970.060	0.000	77.226	219.708	0.000	0.000
Equal variances not assumed			76.091	185,533.350	0.000	0.000

This would make it more sustainable for wine consumers in southern Germany to buy wines from the wine regions in France, Italy, and Spain than those in northern Germany, as the distance travelled is shorter.

The third hypothesis, that the average CO2e values of wine shipments are the same for large and small shipments, must also be rejected. As outlined in Illustration 4-6, in the logistical processing of small consignments, additional consignors or recipients are approached regarding pre- and post-carriage to utilise the loading unit or truck and thus reduce costs. However, this results in more kilometres driven and possibly lower vehicle utilisation than when bundling large shipments, which may even be delivered in a complete truck.

Table 6: Average CO2 equivalents of small and large consignments

Average CO2 equivalents of small and large consignments

	N	Mean	Standard deviation
Small	217,705	71.77	52.46
Large	2,005	37.23	37.82

Source: author's elaboration

Figure 5: t-test statistics for hypothesis 3

Independent Samples Test						
	Levene's Test for Equality		t-test for Equality of Means			
					Significance	
	F	Sig.	t	df	One-Sided p	Two-Sided p
Equal variances assumed	281.256	0.000	29.414	219708	0.000	0.000
Equal variances not assumed			40.539	2075.640	0.000	0.000

Despite the relatively large variance in the mean value for small shipments (classified as under ten tonnes), the test statistics show that the hypothesis must be rejected. Furthermore, no difference in the distribution of small and large shipments was found between northern and southern Germany, so the statement is valuable to know that the shipment weight is an important indicator influencing CO2e value.

Table 7: Average CO2e values of wine shipments delivered directly or via a general cargo network

Average CO2e values of wine shipments delivered directly or via a general cargo network			
	N	**Mean**	**Standard deviation**
Direct shipment	4,658	47.29	44.08
Network	215,052	71.97	52.49

Source: author's elaboration

Figure 6: t-test statistics for hypothesis 4

Independence sample test						
	Levene's Test for Equality of Variances		t-test for Equality of Means			
					Significance	
CO2e_per_bottle	F	Sig.	t	df	One-Sided p	Two-Sided p
Equal variances assumed	346.924	0.000	-31.851	219,708	0.000	0.000
Equal variances not assumed			-37.643	4,947.361	0.000	0.000

As a final hypothesis, in order to obtain more detailed knowledge regarding the logistical influence on the CO2e consumption of wine shipments, it was investigated whether shipments that are delivered directly – e.g., either via collection in the network (see Ill. 6) or one-stage from winery to POS – have lower average CO2e values per shipment than those handled via a logistical network (see Ill. 4 and 5). The null hypothesis that the two mean values are the same must be rejected.

Various wine shipments were simulated to analyse the fifth hypothesis. Several winegrowers in South Africa, Australia, and Chile were selected and simulated in EcoTransIT according to the parameters obtained for how a logistics service provider handles wine shipments.

Corresponding wine shipments were modelled for all three variants in Illustration 8. For variants 1 and 2, fully utilised containers were assumed. In the third variant, it was assumed that only three pallets were transported from the winery to the POS. The POS was assumed to be a warehouse of a food retailer in northern and southern Germany for the whole load and a specialised retailer in the respective region for general cargo delivery.

The calculated CO2e values were compared with corresponding transportation from wineries in Rioja (Spain), Bordeaux (France), and Apulia and Tuscany (Italy). Here, too, a distinction was made between groupage and complete trucks, considering the results of hypotheses 3 and 4. It is presumed that small shipments will be transported via a groupage network and large shipments directly.

To consider the result of the first and second hypothesis, on the one hand, the dataset was analysed to detect the supermarket with the highest transport volume in northern and southern Germany. (The supermarkets' postal codes are 85642 for southern Germany and 44309 for northern Germany.) On the other hand, the location with the highest volume of a wine bar in southern or northern Germany was analysed. (The postal codes with the highest shipment volumes are 28207 for northern and 76889 for southern Germany.) Every wine transport from a winery in this region was analysed to be transported in groupage or as a full truckload to these four customer types. This means four different CO2e values were analysed for all three options in Illustration 7.

For a groupage shipment, three pallets were considered, meaning that a small shipment had 3 / pallet x 600 bottles/pallet x 1.2 kg/bottle = 2,160 kg.

On the other hand, a large shipment consisted of 23 pallets with a transport weight of 16,560 kg.

Before simulating the CO2 values, a few verification tests were completed to make sure that the correct parameters (e.g., utilisation, truck type, empty kilometres, groupage handling) were used in Econtransit in order to meet the CO2e values of the shipments that the logistics service provider had analysed. The values from Italy and Spain correspond to those from the existing shipment data.

For small shipments in Europe, an 18-ton truck of Euro 6 standard with 20% empty runs and 60% weight utilisation was assumed for the pre- and post-transportation. The main haul was a 40-ton truck of Euro 6 standard with 60% weight utilisation and 12% empty runs. This truck type was also used for large shipments or shipments of containers or semi-trailers for combined transportation with rail. In the case of combined transportation, all routes were verified. Rail transportation was only considered if the route could be covered with a maximum of one transhipment. The shortest distance was always selected. Since many of these connections take more than a week because the transhipment time at the train station takes several days, the CO2e calculation was shown but not considered for calculating the mean value. Nevertheless, the CO2e savings potential through rail can be seen when a suitable connection is available.

The C02e values for shipments from the New World were analysed similarly. A random winery in the Stellenbosch region (South Africa), Colchagua region (Chile) or Barossa Valley (Australia) was selected, and transportation was then simulated to the same four postal codes. Again, three transportation options were analysed, as described in Figure 8.

The relevant parameters for EcoTransIT were determined by analysing import data and conducting further interviews with logistics service providers. Here, details of container utilisation, port location and stations close to the railway network, ship type, and LCL organisation were ascertained to ensure the correct parameters were used for EcoTransIT.

For each shipment, the CO2e values for one to five different legs were analysed to calculate the complete CO2e value for this shipment and per bottle.

When looking at the results, one would initially interpret those shipments from New World wineries as having a higher CO2e impact in distribution than Old World wineries. However, this statement is not universally valid. For example, the CO2e values for wines transported from South Africa to northern Germany are lower than those from Apulia or Rioja. Analysing the shipments in greater detail reveals that the logistics networks greatly influence the CO2e of shipments. Thus, it is very hard to make a general statement that wines from the New World in general have a higher carbon footprint than wines from Europe if they are purchased in Germany.

Overall, hypothesis 5 cannot be universally confirmed or rejected. These analyses show that transporting wines from the New World does not necessarily lead to higher CO2 emissions. The CF is lower than wines that are transported to Germany by trucks from more distant European wine regions.

The data in Figures 7 and 8 additionally confirm our hypotheses 1-4 without conducting further statistical tests.

Figure 7: Simulated CO2e value per bottle from different wine regions in southern Europe

Wine region	Logistcs handling / Shipment size	Channel	CO2 per bottle in gramme	Mean
Bordeaux	Small shipment network	Supermarket southern Germany	139.32	127.28
		Supermarket northern Germany	127.51	
		Vinothek southern Germany	115.97	
		Vinothek northern Germany	146.32	
	Large shipment direct	Supermarket southern Germany	130.98	
		Supermarket northern Germany	112.59	
		Vinothek southern Germany	110.60	
		Vinothek northern Germany	134.97	
	Large shipment direct incl. rail	Supermarket southern Germany	unrealistic	
		Supermarket northern Germany	unrealistic	
		Vinothek southern Germany	unrealistic	
		Vinothek northern Germany	unrealistic	
Rioja	Small shipment network	Supermarket southern Germany	176.13	165.15
		Supermarket northern Germany	164.23	
		Vinothek southern Germany	152.57	
		Vinothek northern Germany	183.20	
	Large shipment direct	Supermarket southern Germany	168.84	
		Supermarket northern Germany	150.87	
		Vinothek southern Germany	148.87	
		Vinothek northern Germany	176.48	
	Large shipment direct incl. rail	Supermarket southern Germany	35.94	
		Supermarket northern Germany	41.09	
		Vinothek southern Germany	35.26	
		Vinothek northern Germany	38.98	
Apulia	Small shipment network	Supermarket southern Germany	149.98	175.84
		Supermarket northern Germany	191.28	
		Vinothek southern Germany	166.28	
		Vinothek northern Germany	201.80	
	Large shipment direct	Supermarket southern Germany	137.57	
		Supermarket northern Germany	192.18	
		Vinothek southern Germany	159.40	
		Vinothek northern Germany	208.27	
	Large shipment direct incl. rail	Supermarket southern Germany	38.14	
		Supermarket northern Germany	unrealistic	
		Vinothek southern Germany	45.52	
		Vinothek northern Germany	50.63	
Tuscany	Small shipment network	Supermarket southern Germany	89.27	112.25
		Supermarket northern Germany	130.57	
		Vinothek southern Germany	105.56	
		Vinothek northern Germany	141.09	
	Large shipment direct	Supermarket southern Germany	71.09	
		Supermarket northern Germany	125.70	
		Vinothek southern Germany	92.92	
		Vinothek northern Germany	141.79	
	Large shipment direct incl. rail	Supermarket southern Germany	unrealistic	
		Supermarket northern Germany	44.00	
		Vinothek southern Germany	unrealistic	
		Vinothek northern Germany	41.80	

Figure 8: CO2e value per bottle for shipments from the New World

Wine region	Logistcs handling / Shipment size	Channel	CO2 per bottle in gramme	Mean
Chile (Colchagua)	FCL	Supermarket southern Germany	192.42	172.77
		Supermarket northern Germany	130.92	
		Vinothek southern Germany	175.84	
		Vinothek northern Germany	129.31	
	FCL with rail	Supermarket southern Germany	124.22	
		Supermarket northern Germany	115.14	
		Vinothek southern Germany	126.48	
		Vinothek northern Germany	129.31	
	LCL	Supermarket southern Germany	258.82	
		Supermarket northern Germany	253.62	
		Vinothek southern Germany	245.60	
		Vinothek northern Germany	191.59	
South Africa (Stellenbosch)	FCL	Supermarket southern Germany	184.09	156.63
		Supermarket northern Germany	120.07	
		Vinothek southern Germany	167.52	
		Vinothek northern Germany	107.23	
	FCL with rail	Supermarket southern Germany	115.89	
		Supermarket northern Germany	104.30	
		Vinothek southern Germany	118.15	
		Vinothek northern Germany	99.75	
	LCL	Supermarket southern Germany	237.71	
		Supermarket northern Germany	231.23	
		Vinothek southern Germany	224.49	
		Vinothek northern Germany	169.09	
Australia (Barossa Valley)	FCL	Supermarket southern Germany	275.18	251.25
		Supermarket northern Germany	215.38	
		Vinothek southern Germany	258.61	
		Vinothek northern Germany	201.01	
	FCL with rail	Supermarket southern Germany	206.98	
		Supermarket northern Germany	199.60	
		Vinothek southern Germany	209.24	
		Vinothek northern Germany	193.53	
	LCL	Supermarket southern Germany	336.71	
		Supermarket northern Germany	334.12	
		Vinothek southern Germany	323.49	
		Vinothek northern Germany	261.20	

5. Conclusion

To summarise, this study has shown that the CF for the distribution of wine shipments cannot be generalized. Checking how the shipment was handled in a logistics network is necessary. The distance, shipment size and logistical handling all influence the CO2e value.

The study also shows that it would be too simplistic to look at the CO2e emissions of wine shipments in general, as the distribution channel and the region bear a significant influence.

It could also be shown that the different logistical handling of the wine shipments also means that wines from the New World do not have worse CO2e emissions per se. As a figure, if the CO2 emissions from viticulture and wine production are added, this could lead to different results. Figure 1 shows that the CO2 values for electricity generation or irrigation may increase the carbon footprint for wines from the New World more than from wineries in Europe. However, this would have to be analysed in greater detail and could only be determined on a winery-by-winery basis. In general, however, it can be said that wines from the New World do not need to be categorised more critically in terms of sustainability.

6. Limitations

Although the study was conducted using several thousand data records, it was assumed that logistics processing conducted by other logistics service providers is identical or that any deviation due to different locations of transhipment points or changes in capacity utilisation is negligible. Furthermore, the shipments considered between the Old and New World were simulated and do not refer to real shipments. Although existing reference shipments showed identical results, unforeseen events or a lack of bundling capability could change the results.

If different wineries were selected to analyse the fifth hypothesis and Points of Sale, this would lead to slightly different CO2e values. However, the overall data shows that the central assumption can be confirmed.

Another simplification used for this research was deeming the weight of a glass bottle to be 450g. In reality, this could vary between 250 and 750g. However, this was the only way to calculate the CO2e per bottle reasonably.

7. Recommendation for further research

Due to the high standard deviation in the existing results of the PCF calculation within the various system boundaries of the wine LCA, more data would have to be analysed in order to obtain more explicit statements and to be able to analyse possible reasons for this deviation better.

Concerning distribution, it would be interesting to analyse further data for wine deliveries conducted by other logistics service providers to verify the validity of the existing results.

Overall, however, the study provides an excellent insight into the factors influencing CO2e levels in wine distribution.

Suppose the exact CO2e ascertained to be generated by distribution in this study is added to the various values of the CO2e determined for the viticulture and wine production of a bottle of 850g with a significant standard deviation (between 200g to 2000g). In that case, it can be seen that the distribution process – accounting for between 60g and 250g – has a smaller share (and where rail shipment is possible, this could be even lower). Since the CO2e values for some transports from the New World wine areas are even lower than those for distant wine-growing regions in Europe (Spain, Portugal, and southern Italy), it was shown that this influence should not affect the end consumer's purchasing decision. However, it is assumed that many consumers have a negative attitude towards wines from the New World due to their potential environmental impact.

About the author

Professor Dr Martin Göbl has been lecturing in logistics and business management at Kempten University of Applied Sciences, Germany, since 2006.

After graduating as an industrial engineer, he worked in different functions and positions in logistics management, during which time he also earned a PhD. His research interests lie in evaluating services, strategic logistics management and logistics service providers.

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