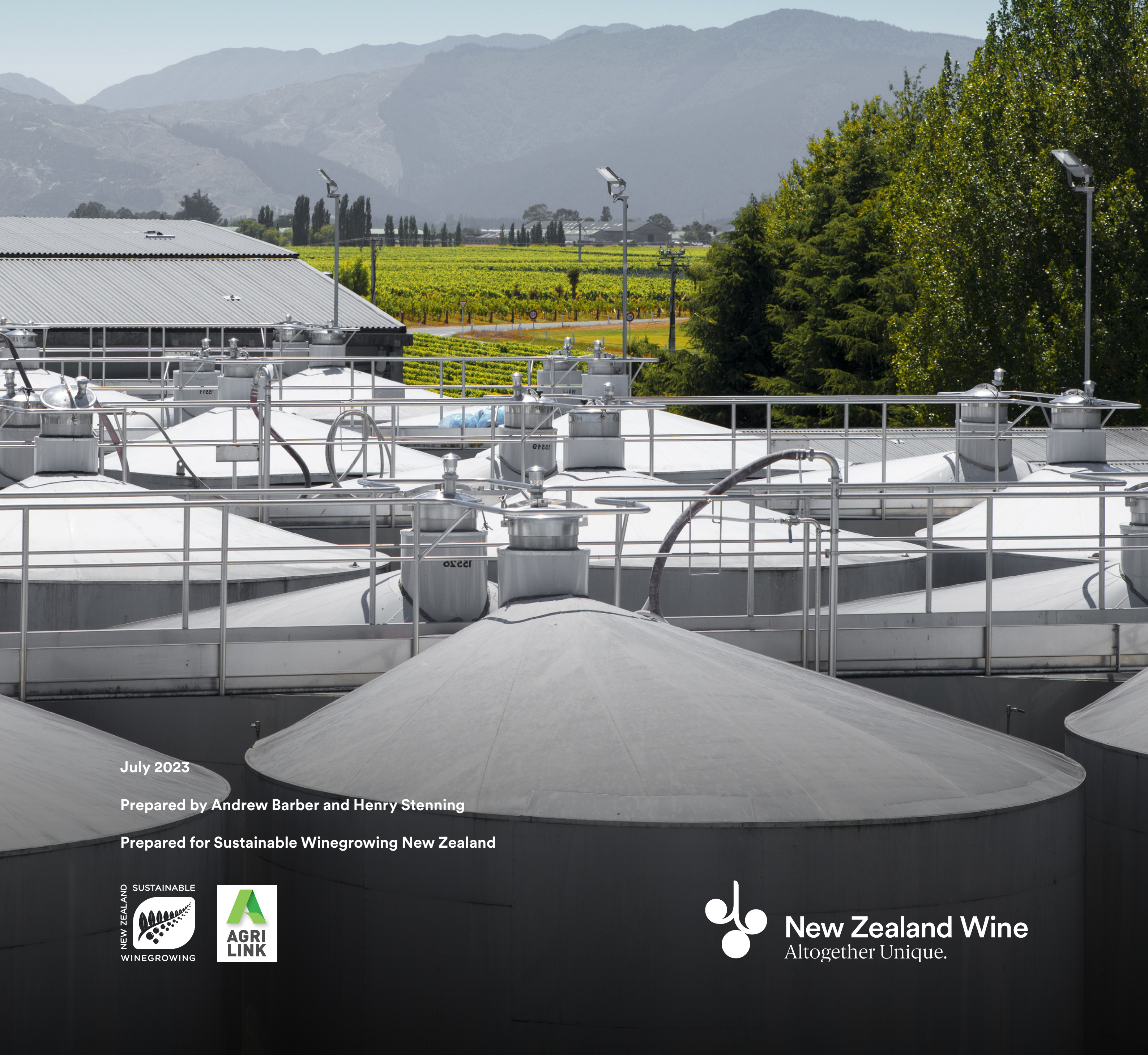
National Greenhouse Gas Emissions Report 2022

Questionnaire Reporting, Benchmarking and Tracking - Vintage 2022



July 2023

Prepared by Andrew Barber and Henry Stenning

Prepared for Sustainable Winegrowing New Zealand

New Zealand Sustainable Winegrowing

Agri Link

New Zealand Wine
Altogether Unique.

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Snapshot - Greenhouse Gas Emissions

- This is the second national greenhouse gas (GHG) report for the New Zealand wine industry prepared using the Sustainable Winegrowing New Zealand (SWNZ) WiSE Questionnaires and Grapelink plant protection diaries. It has been prepared to continue quantifying and tracking the industry's GHG emissions. NZ Winegrowers' goal for the climate change focus area is for the NZ wine industry to be carbon neutral by 2050.

- This national report builds upon the individualised GHG emission benchmarking reports that were sent to all SWNZ vineyard and winery members.

- This report does not quantify the full carbon footprint of wine. It captures GHG emissions from energy, plant protection chemistry, and fertiliser (manufacturing and field emissions), as well as for the first-time winery transport and packaging. GHG life cycle emission factors are used, which aligns with the future goal of being able to support the industry report and track the carbon footprint for a bottle of wine.

- Estimated GHG emissions resulting from wine production, to the winery door, was 131,768 t CO_2e for the 2022 vintage (2021/22 season), equivalent to 258 g CO_2e/bottle of wine. Vineyards accounted for 41% of these emissions. Winery packaging accounts for 44% of total emissions. The balance being winery electricity (7%), winery fuel (4%) and transport between vineyard and winery and between wineries (4%).

- Within the vineyard, diesel use produces the most GHG emissions at 720 kg CO_2e/ha. Very little petrol is used and consequently only accounts for 35 kg CO_2e/ha. Electricity use on vineyards accounts for 52 kg CO_2e/ha.

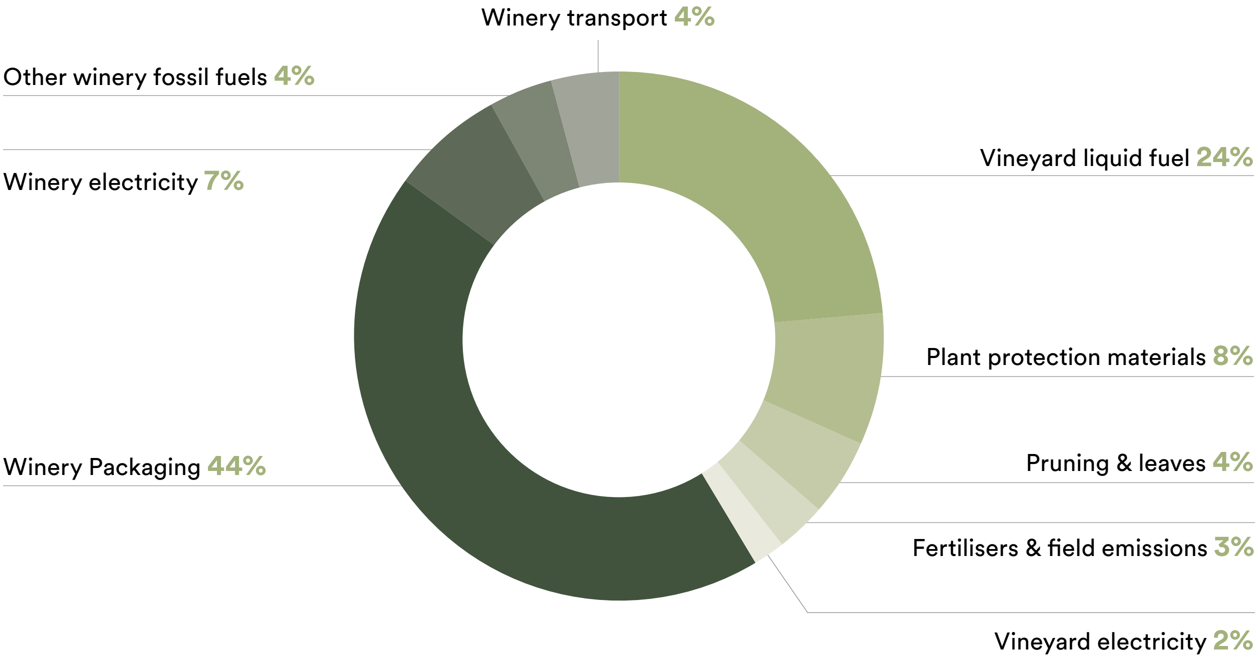
- Plant protection (agrichemical) manufacturing emissions are the second largest contributor to vineyard emissions, at 260 kg CO_2e/ha. Emissions from fertiliser manufacturing and field emissions following their application are 37 and 46 kg CO_2e/ha, respectively. Organic material applied to the soil results in nitrous oxide emission during decomposition. This includes emissions from the estimated quantity of prunings and leaf fall at 129 kg CO_2e/ha, and grape marc resulted in 15 kg CO_2e/ha being emitted on average.

- Life cycle GHG emissions from winery electricity use was 23 g CO_2e/L wine (17 g CO_2e/bottle) in the 2022 vintage. This is a 29% decrease when compared to the previous vintage.

- The other major energy sources used in wineries are diesel, petrol, natural gas, and LPG. Emissions from these fossil fuels were reported on for the first time in the individualised winery energy & GHG benchmarking reports and were on average 15 g CO_2e/L wine. Based on a national average, electricity accounts for 61% of winery energy source emissions, while diesel and LPG account for 21% and 16% respectively.

- Transport of grapes and bulk liquid account for 4% of total wine production emissions, dominated by emissions resulting from trucking.

- By far the largest source of emissions from wine production occurs during the packaging phase, accounting for 44% of total emissions. This is also the largest source of uncertainty in the calculated emissions due to the large diversity in packaging types, material, and reporting. The packaging emissions are also very dependent upon the system boundary, which in this case is to the winery door. Therefore, those wineries that have their wine leave in bottles have their bottle emissions included, while wine distributed in bulk tank for later packaging into bottles do not include the emissions from glass as that occurs beyond the winery door.



Distribution of GHG emissions across the NZ wine industry, from grapes to packaged wine leaving the winery.

1.0 Vineyard Greenhouse Gas Emissions

An individualised benchmarking report for vineyard GHG emissions was prepared for SWNZ members for the second time following its introduction last season. The second edition of this report has been extensively updated, incorporating new emission sources, new methodologies for emission calculation, and new data visualisations.

This report contains an emissions breakdown from data provided in the WiSE Questionnaires and in Grapelink spray diaries. An example of this report is shown in the appendix.

This data has enabled an analysis of vineyard GHG emissions for the 2021/22 season. It should be noted that this is not a full LCA study due to limitations in the data collected. However, enough data has now been collected through Questionnaires and spray diaries to provide a robust estimate of the industries vineyard emissions profile.

1.1 Vineyard Energy Emissions

The energy sources collected in the WiSE Questionnaires are shown in Table 1, along with their average usage and total emissions. Total emissions have been estimated using the average per hectare usage multiplied by the total area recorded in the New Zealand Wine Annual Report 2022 (41,603 ha). Other energy sources provided by vineyards have been excluded from this analysis and from the benchmark reports due to insufficient data.

Table 1. Energy sources, usage, and emissions

Category	Unit	Average quantity (unit/ha)	Emission factor[1] ($kgCO_2e$/unit)	GHG emissions ($kgCO_2e$/ha)	Industry GHG emissions[a] (tCO_2e)
Diesel	L	229	3.147	720	29,961
Petrol	L	13	2.760	35	1,462
Electricity	kWh	395	0.133	52	2,178

a. Based on a total planted area of 41,603 ha

Diesel accounts for most of the energy emissions on vineyards, contributing 89% of total vineyard energy emissions. While estimated diesel use by contractors is asked for in the WiSE Questionnaire, this is very difficult to capture and therefore it may not be fully reported. Therefore, actual diesel use may be slightly higher than reported here.

Reduction in diesel use presents the greatest opportunity for reducing energy intensity on vineyards. This is a combination of improved technology and reducing the number of passes possibly through multiple tasks in a single pass. Some examples from both New Zealand (https://www.oxin.nz/) and overseas showcase the possibilities (https://tinyurl.com/ywh2f8uy).

1.2 Vineyard Fertiliser and Agrichemical Manufacturing Emissions

Table 2 shows the GHG emissions from the manufacturing and transport of fertiliser and agrichemicals. The other major emission source for nitrogen, lime and dolomite are field emissions. These are shown in Section 1.3.

There are two methods for calculating fertiliser GHG emissions. Either, where available, using a product's specific GHG emission value; or calculating the emissions based on the sum of the product's emissions per element. For example, ammonium sulphate has a product specific emission factor of 0.77 kg CO_2e/kg product (McLaren et al.,

[1] Barber, A., and Stenning, H., 2022. New Zealand fuel and electricity total primary energy and life cycle greenhouse gas emission factors 2022. http://agrilink.co.nz/casestudy/life-cycle-assessment-nz-fuel-and-electricity/

2021), but 0.82 kg CO_2e/kg product when calculated as the sum of its elements (20% non-urea nitrogen and 23% sulphur = 0.2 * 3.75 + 0.23 * 0.3) = 0.82 kg CO_2e/kg product).

Table 2. Fertiliser and agrichemical manufacturing emissions

Category	Average quantity (kg ai/ha)[a]	Manufacturing emission factor (kgCO_2e/kg)	GHG emissions (kgCO_2e/ha)	Industry GHG emissions (tCO_2e)
Fertiliser[b]			**37.0**	**1,539**
Fertiliser - calculated from individual elements[c]			**43.2**	**1,798**
Urea nitrogen	0.5	2.12[e]	2.5	105
Non-urea	5.4	3.75[e]	23.3	971
Phosphorous	3.2	1.85[e]	5.9	247
Potassium	6.6	0.86[e]	5.7	238
Sulphur (as fertiliser)	8.2	0.32[e]	2.6	109
Magnesium	4.1	0.32[e]	1.3	55
Lime	23.3	0.04[e]	0.9	39
Dolomite	10.3	0.08[e]	0.8	34
Agrichemicals[d]	-	-	**249.1**	**10,363**
Fungicide	3.4	15.7 (1.2)	62.2	2,586
Inorganic fungicide (copper & sulphur)	37.4	0.3 (1.5)	87.8	3,652
Herbicide	5.2	10.1 (1.7)	74.4	3,095
Insecticide	0.2	16.0 (1.5)	6.3	261
Oils	2.9	0.6 (1.5)	8.9	371
Other[f]	6.8	Varies	9.6	399

a. Quantity of element or active ingredient. Total quantity applied divided by total area in the Grapelink database (40,760 ha)

b. Fertiliser emissions are based on specific product emissions, and where these are not available then the constituent parts. This is the figure used to determine total emissions from fertiliser manufacturing.

c. Fertiliser emissions calculated from the constituent parts of all fertilisers, including those that we have a specific product emission factor for. This second approach is included in the analysis to provide a sense of how much each element contributes to the fertiliser manufacturing emissions.

d. Agrichemicals have two emission factors: Manufacturing, which is applied to the quantity of active ingredient, and Transport/Packaging, which is applied to the total quantity of product. The latter is shown in Table 2 in brackets. (The methodology for determining these emission factors is described in Appendix 2).

e. McLaren S., Clothier B., Barber A., McNally S., Bullen L., Mazzetto A., Ledgard S., 2021. Updating The Carbon Footprints for Selected New Zealand Agricultural Products - an update for apples, kiwifruit and wine. Prepared for Ministry for Primary Industries. https://www.mpi.govt.nz/dmsdocument/51079-Updating-the-carbon-footprint-for-selected-New-Zealand-agricultural-products-an-update-for-apples-kiwifruit-and-wine Specific nitrogen and phosphorous products such as CAN and single superphosphate have unique emission factors.

f. Other refers to all other agrichemical products including adjuvants, wetters, spreaders etc. Usage shown is full product rate, as there is often no active ingredient information for these products.

1.3 Vineyard Field Emissions

Field emissions result from the release of nitrous oxide from synthetic nitrogen fertiliser. For emissions calculations, nitrogen fertiliser is divided into non-urea, urea, and urea with urease inhibitors. Nitrogen fertiliser use averaged 5.5 kgN/ha, of which urea was 0.5 kgN/ha.

There are no recorded uses of urea fertiliser with urease inhibitors in the wine industry. Nitrogen is also applied to vineyards in the form of organic nitrogen typically seaweed extracts or amino acids. These have not been quantified due to the lack of product information.

Nitrous oxide emissions came to approximately 1,322 t CO_2e from the application of synthetic nitrogen fertiliser in the 2021/22 season. This is an average of 31.8 kg CO_2e/ha, or 2.5 kg CO_2e/tonne grapes produced.

Application of lime and dolomite also releases greenhouse gases in the form of carbon dioxide. Carbon dioxide emissions came to approximately 568 t CO_2e from the application of lime and dolomite, equivalent to 13.7 kg CO_2e/ha or 1.1 kg CO_2e/tonne gapes produced.

The other source of field emissions is nitrous oxide released from the breakdown of organic matter. The main sources of organic matter breaking down on vineyard soils are leaves, prunings, and grape marc.

In this analysis and the individualised reports, the quantity of nitrogen embodied in leaf fall and prunings was based on an average of 30 kgN/ha[2]. This was set as the level of nitrogen at the national average level of production (12.9 t/ha), with individual vineyard emissions scaled using their production. A linear regression was based on half the yield equating to 25% less canopy. Therefore, an average yield in Otago of 6.8 t/ha has an estimated nitrogen content of 22.9 kgN/ha.

The fraction of this nitrogen that is released was determined using the IPCC 2006 methodology for direct soil emissions = kgN × EF1 × 44/28 × GWP N_2O. EF1 = 0.01, and the latest Global Warming Potential for N_2O is 273 (AR6[3]). The emission factor is 4.2 kg CO_2e/kgN.

At a national average of 30 kg N/ha deposited on the soil surface through leaf fall and prunings, the average per hectare emissions from breakdown of this leaf residue are 129 kg CO_2e/ha, or 5,364 t CO_2e across the industry.

Emissions from the breakdown of grape marc spread on vineyard soils are calculated in the same way. Australian research found grape marc to have an average nitrogen content of 1.8% (% dw), 46% dry matter (w/w), and a bulk density of 845 kg/m^3 [4]. The quantity of grape marc spread on vineyards varies enormously averaging 0.5 m^3/ha, resulting in per hectare emissions of 15 kg CO_2e/ha, or 619 t CO_2e across the industry.

1.4 Total Vineyard GHG Emissions

Total estimated GHG emissions from vineyards for the 2021/22 season were 53,376 t CO_2e. This equates to approximately 1,283 kg CO_2e/ha. Using NZ wine Annual Report 2022 production volumes, vineyard activities contribute 139 g CO_2e/L produced by the industry, or 105 g CO_2e/bottle.

2. Clothier B, Müller K, Hall A, Thomas S, van den Dijssel C, Beare M, Mason K, Green S, George S. 2017. Futures for New Zealand's arable and horticultural industries in relation to their land area, productivity, profitability, greenhouse gas emissions and mitigations. Plant & Food Research report provided for New Zealand Agricultural Greenhouse Gas Research Centre. SPTS No. 14440.

3. IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change[Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, In press, doi:10.1017/9781009157896.

4. Patti, A.F., Issa, J., and Wilkinson, K., 2004. What are we putting on the ground? Characterisation of Grape Marc Composts from the Goulburn and Yarra Valley Regions of Victoria. Monash University. https://www.wineaustralia.com/getmedia/f1ba0102-f02f-40f0-8ede-567643cd87e7/RT-02-42-and-RT-02-43 (accessed 29/9/22).

Figure 1 provides a breakdown of vineyard emissions by source. Diesel use on vineyards is the largest contributor to total emissions, followed by the emissions from plant protection (agrichemical) manufacturing. Reducing diesel use and decreasing the use of synthetic plant protection products therefore provides the greatest opportunity for reducing vineyard emissions.

This season saw a 13% increase in total vineyard emissions from the previous season, driven by increases in all categories of emissions, except for electricity and plant protection. Part of the increase was driven by a 3% increase in recorded production area. On a per hectare basis there was a 9% increase compared to the previous season. This season also had a much higher level of production (44% increase) – both total and per hectare - than last season, therefore, when adjusted for the volume of wine produced, this season saw a significant 22% fall in emissions per litre of wine.

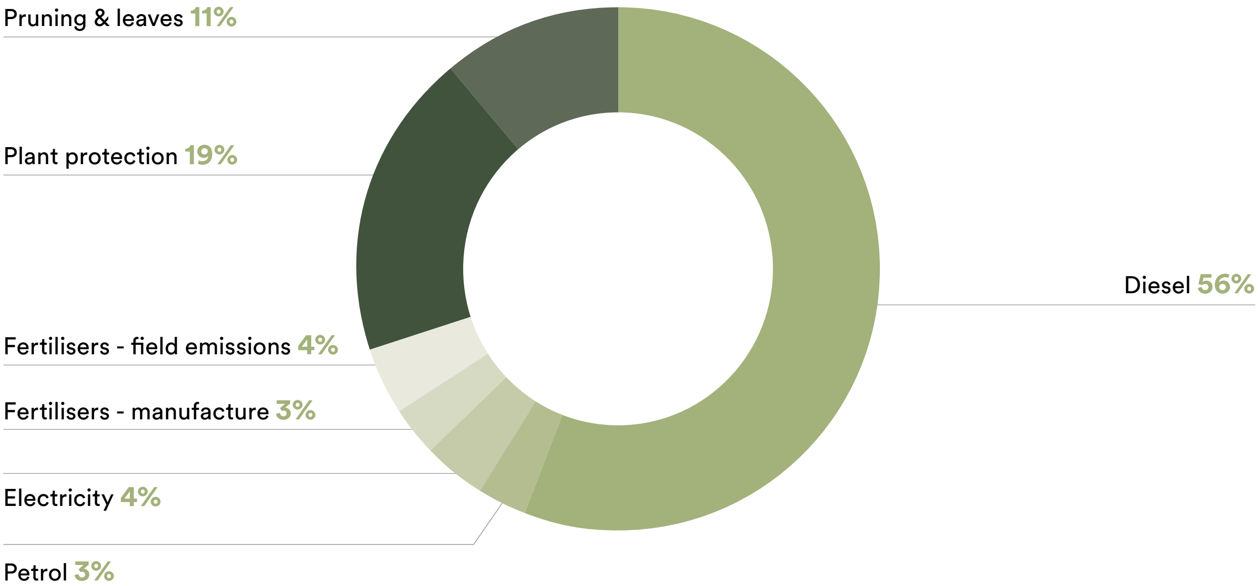


Figure 1. Proportion of vineyard GHG emissions by source

Table 3. Vineyard emissions by source and year

Category	GHG emissions (kg CO_2e/ha)		GHG emissions (g CO_2e/L wine)		Industry GHG emissions (t CO_2e)	
	2021	2022	2021	2022	2021	2022
Total	**1,176**	**1,283**	**178.0**	**139.4**	**47,536**	**53,376**
Energy	739	808	111.8	87.7	29,786	33,600
Diesel	642	720	97.1	78.2	25,865	29,961
Petrol	34	35	5.1	3.8	1,362	1,462
Electricity	63	52	9.6	5.7	2,556	2,178
Fertiliser	57	82	8.6	9.0	2,281	3,430
Manufacturing	-	37	-	4.0	-	1,539
Field emissions	-	45	-	4.9	-	1,890
Agrichemicals	261	249	39.5	27.1	10,518	10,363
Prunings, Leaves, Marc & Waste	120	144	18.1	15.6	4,820	5,983

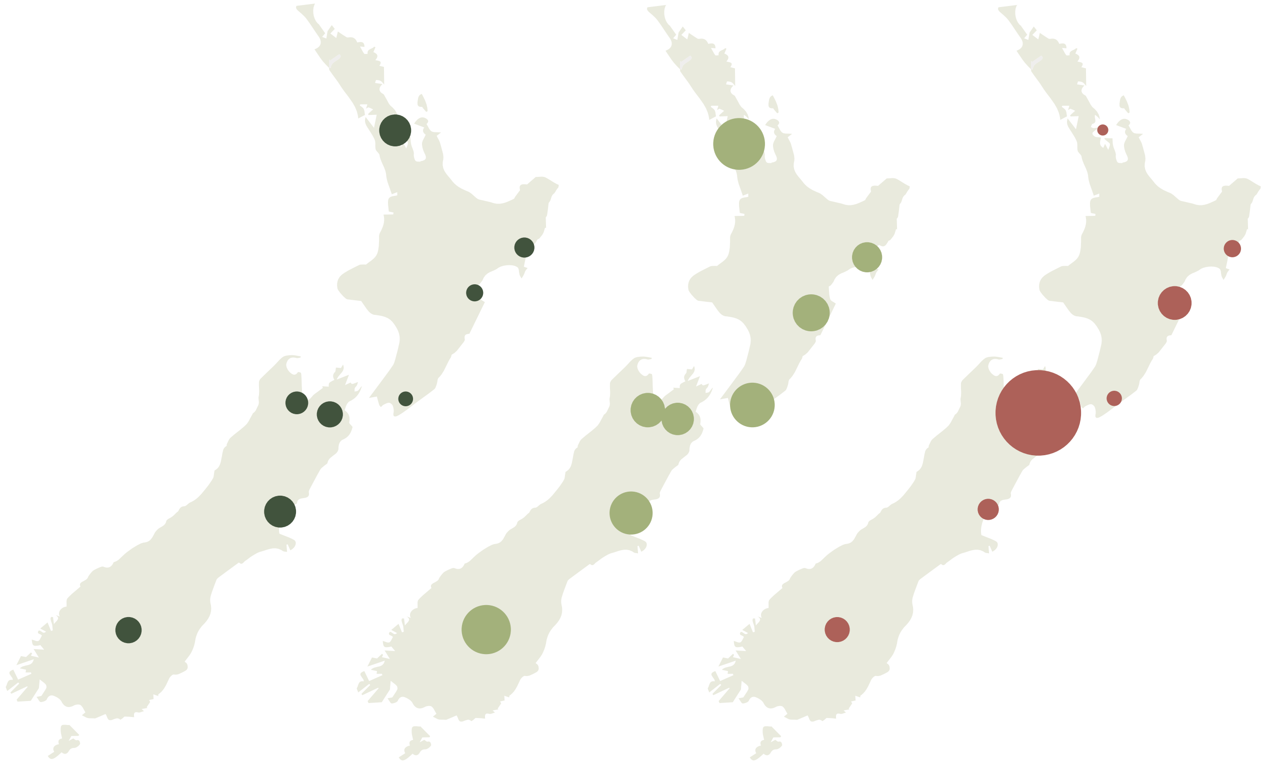


Figure 2. Relative regional average kg CO_2e/ha (left - ●) kg CO_2e/t (centre - ●), and total t CO_2e (right - ●).

2.0 Winery Greenhouse Gas Emissions

2.1 Winery Energy

2.1a Winery Questionnaire Participation

Winery Annual National Energy Use Reports date back to 2011. With over a decade of consistently collected and reported data there is a solid database that can be used to observe multi-year changes across the industry.

The analysis and reports are based on the information that was extracted from the Sustainable Winegrowing New Zealand (SWNZ) WiSE Questionnaires. This download was performed on the 12th of September 2022, at which point the database contained 192 Winery Questionnaires.

Of the 192 Winery Questionnaires received 9 were for bottling only wineries. The remaining 183 wineries have been analysed together as it has been found that winery type (wineries can select various processing combinations, e.g., with or without bottling) explained very little of the variation. Combining them provided a more robust result. Generally, the most significant determining factor for energy use per litre of wine is winery size.

Seventy-six percent of the analysed wineries (139 wineries) provided some energy use data, a slight decrease on the previous season. 119 (65%) of these were included in the electricity use analysis, compared to 116 (67%) in the previous vintage.

Wineries were excluded from the electricity analysis if they fell outside the anticipated electricity intensity range of 50 to 2,000 kWh/kL wine, as these were likely to be data entry errors. Likewise, they were excluded from the natural gas and LPG analysis if they exceeded 15,000 MJ combined gas/kL wine, and from the petrol and diesel analysis if they exceeded 1,000 L/kL wine.

While 86% of all wineries provided some data (production and/or electricity), 65% were included in the electricity analysis. 85% of wineries provided production data, significantly more than provided energy use data. Larger wineries were more likely to have completed the questionnaire by the download date, therefore 88% of questionnaire recorded production was included in the electricity analysis, an increase on the 65% last vintage.

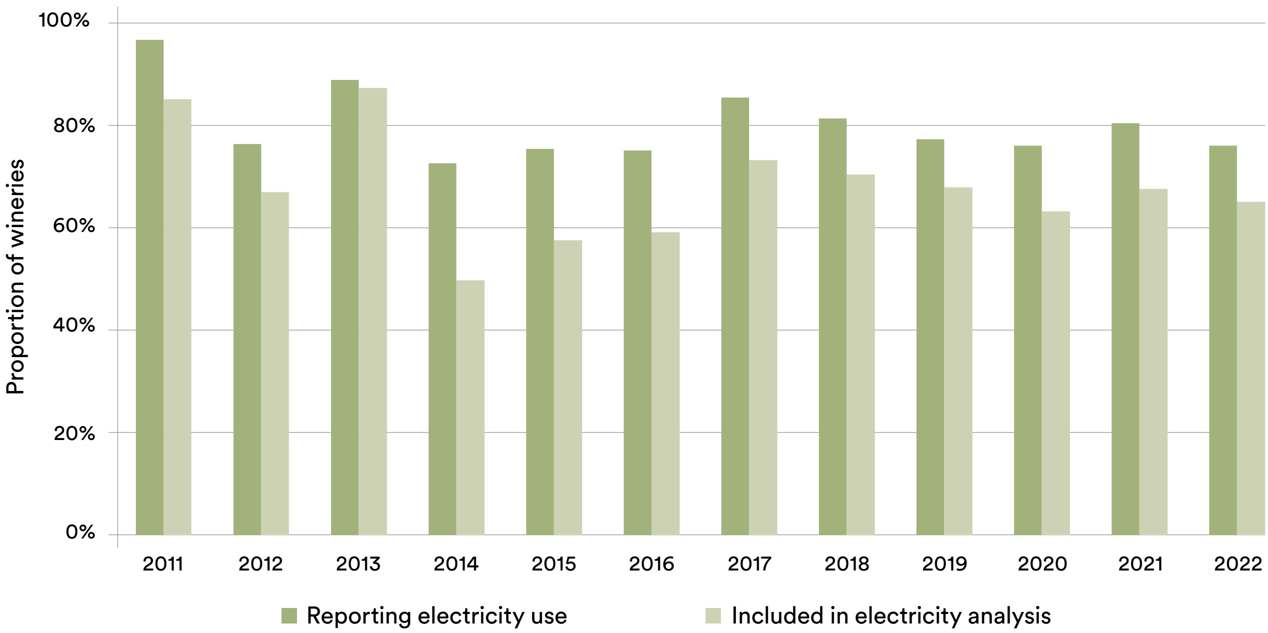


Figure 3. Percentage of wineries that provided electricity use and those that were included in the analysis from 2011 to 2021 (excluding bottling only facilities)

The proportion of winery production included in the analysis as a percentage of total recorded production (for non-bottling/crushing only wineries) has risen to 88% (Figure 4). This mainly reflects greater participation from > 4 mL sized wineries this season when compared to last.

The total included production was 85% greater than last season, at approximately 364,900 kL (197,120 kL in 2021). This is 95% of the production recorded in the NZ Wine Annual Report 2022 of 383,000 kL, which is collected through a separate winery survey.

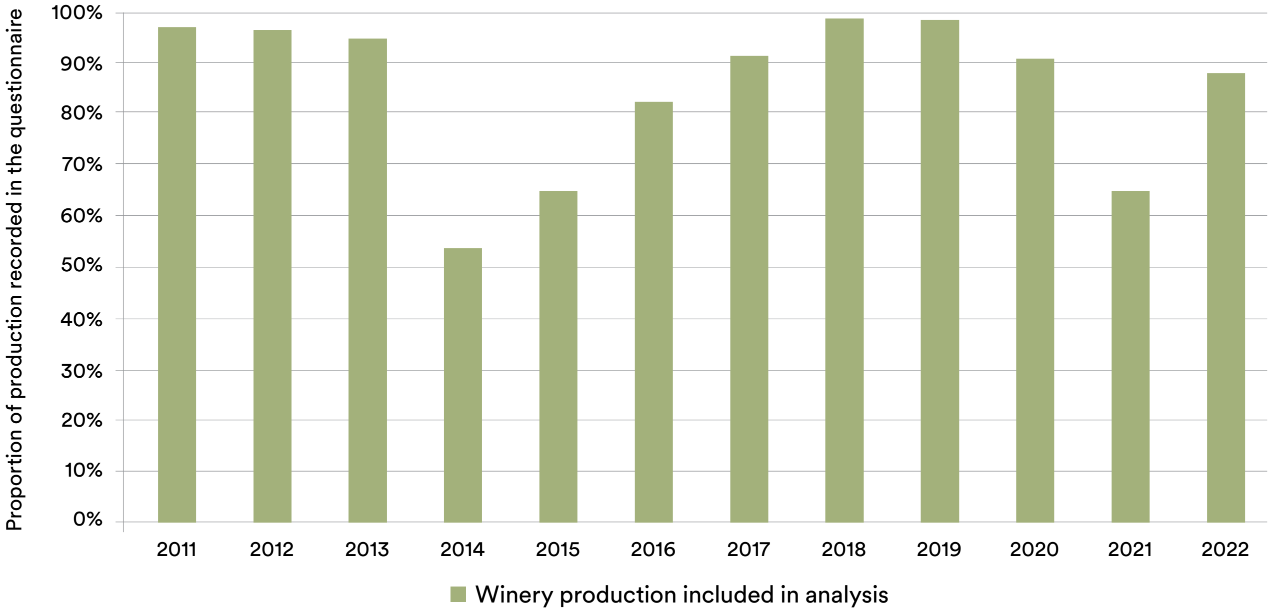


Figure 4. Percentage of production that is included in the analysis from 2011 to 2022.

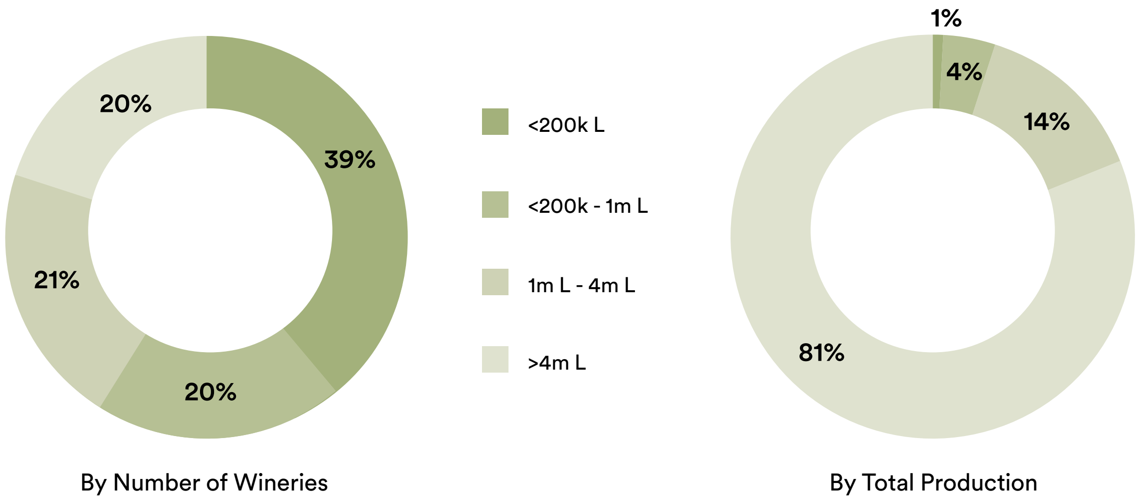


Figure 5. Winery size distribution by number and production.

Table 4 shows the number of wineries and production as reported through the NZ Wine Annual Report and SWNZ WiSE Questionnaire by winery size (Figure 5). NZ Wine includes site and no-site wineries in their winery number, whereas WiSE captures physical (site) wineries. The biggest disparity is in the <200kL category, though interestingly this season there are more >4 mL wineries reported in the Questionnaire than in the Annual Report, though this may just reflect differences between sales and production volumes.

Production is also captured differently, although included production for this vintage is within 5% of the Annual Report.

Raw production in the questionnaire exceeds that of the Annual Report. This is likely due to production unit or data entry errors from some wineries, with these excluded from this analysis. Efforts are made when preparing the individualised reports to identify and correct for unit errors, however in some cases it is not possible to positively identify data entry errors and so the production volumes are not changed.

Table 4. **Number of wineries in WiSE data and NZ Wine Annual Report**

	< 200k L	200k - 1m L	1m - 4m L	> 4m L	Total
NZ Wine Annual Report 2022:					
Total wineries	662	66		16	744
Total production (kL)	-	-		-	383,000
Total wineries in WiSE*	84	39	30	29	182
Total production in WiSE (kL)*	4,955	15,385	59,742	334,527	414,612
Number of wineries included in the energy analysis	46	25	25	24	120
Production included in the energy analysis (kL)	3,846	13,496	52,170	295,393	364,906

*Excluding bottling only wineries, crushing only wineries, wineries that are resigned, inactive and No-Site Wineries. Note, the annual report and WiSE data is collected through different survey methods. Invariably there will be small differences. The total national GHG emissions are scaled, based on a per litre metric, to the production recorded in the Annual Report.

2.1b Winery Energy Use

All results are reported as industry averages, that is total energy use divided by total production. In previous years, individualised benchmarking reports compare a wineries performance against winery averages (the average of individual wineries), hence why there was often a small difference between the averages in this national report compared to the comparable figure in the individualised reports. In a review of the reporting programme this season it was decided to align both report methodologies for consistency and clarity, therefore industry averages are used in both the individualised reports and this national analysis.

An example of the single page energy and GHG emissions benchmarking report that is sent to all wineries is included in the appendix.

Table 5 summarises the winery response rate and energy use for each vintage since 2012.

Overall electricity intensity has decreased this year from 245 kWh/kL in 2021 to 175 kWh/kL this vintage, a significant change. This vintage had the joint lowest winery electricity intensity since reporting began (equal with 2017), meanwhile the 2021 vintage had the second highest electricity intensity over the same period (just behind the 2012 vintage).

There are often moderate changes in electricity intensity between years due to various factors, specifically production volumes, as base level electricity use is mostly independent of production volumes, so looking at a 2-year rolling average may be more useful as a guide to the overall trend.

Based on a two-year rolling average electricity intensity has decreased by 10% between 2012 and 2022, with an average across this period of 210 kWh/kL wine, with a seasonal variation of approximately 40 kWh/kL.

Table 5 shows total energy use (electricity, gas, diesel, and petrol) in megajoules. Some caution is needed around the gas and liquid fuel figures as there was a lot of variation between wineries. This may reflect inherent variation between wineries with different systems, their access to natural gas, or data entry errors in the Questionnaire. Relatively low levels of participation in these questions also make it difficult to distinguish between false 0's and no usage (i.e., questionnaires with no LPG data may not use LPG, or may have just not entered their data which would affect reported averages).

As with the previous vintage no bottling-only individualised reports were produced due to the low number of wineries (there were just 2 this season with both electricity and production data); meaning there was limited merit in producing a report and possible data confidentiality issues. Table 5 contains data from bottling only wineries where four or more had included data for a given vintage.

Table 5. Winery energy use

Vintage	Number of submitted Questionnaires	Number with recorded elec. use[a]	Electricity (kWh/kL wine)	Gas[b] (MJ/kL wine)	Liquid fuels[c] (MJ/kL wine)	Energy[d] (MJ/kL wine)
	Wineries (excl. bottling only)					
2022	**183**	**139**	**175**	**95**	**115**	**845**
2021	172	138	245	75	155	1,115
2020	200	152	190	85	135	900
2019	198	153	195	60	100	870
2018	192	156	225	70	95	980
2017	185	158	175	55	70	765
2016	180	135	225	55	80	950
2015	169	127	230	55	70	945
2014	153	111	180	45	330	1,020
2013	131	116	200	120	-	870
2012	169	129	260	150	-	1,040
		Bottling only[e]				
2022	**9**	**6**	**-**	**1**	**-**	**-**
2021	9	6	40	3	26	180
2020	10	8	130	1	2	460
2019	10	7	30	1	2	130
2018	9	9	40	13	4	140
2017	9	8	40	14	0	160
2016	9	5	-	-	-	-
2015	7	6	-	-	-	-
2014	1	0	-	-	-	-
2013	15	12	130	160	-	640
2012	11	9	90	80	-	390

a. Some of these wineries recorded electricity but were excluded as they fell outside the anticipated range

b. Gas = Natural gas plus LPG, reported in megajoules per 1,000 litres of wine. Questionnaire records for gas are less comprehensive than for electricity, so intensity varies significantly between seasons.

c. Liquid fuels include petrol and diesel. Questionnaire records for liquid fuels are less comprehensive than for electricity, so intensity varies significantly between seasons.

d. Energy = Electricity plus natural gas, LPG, diesel, and petrol. Reported in megajoules per 1,000 litres of wine. Total energy use from all sources divided by total production.

e. The anticipated range for bottling only wineries is wider (10 – 2,000 kWh/kL wine) to account for lower electricity use. Averages are only presented here where 4 or more wineries were included.

Note: 1 kWh = 3.6 MJ.

Table 6 and Figure 6 shows the variation in electricity intensity by winery size. Size is the single largest determinant of electricity intensity. This underscores the importance of reporting benchmarks that are tuned by winery size. However, that large variation, particularly in the Category 1 wineries, may also demonstrate the opportunity for further improvement by individual wineries. There is a 28-fold difference in electricity efficiency for Category 1 wineries between the highest and lowest electricity efficient wineries, compared to just a 4-fold difference for Category 4 wineries.

Category 1 wineries account for just over 1% of production and may have limited opportunities to improve energy efficiency due to lack of inherent efficiencies that arise from greater production volumes. While reductions in base level electricity usage by these smaller Category 1 and 2 wineries may increase individual efficiencies, from a total industry perspective the electricity usage of the largest wineries has the most impact, Figure 7 shows the impact that Category 4 winery electricity usage has on the overall industry average.

Production volume is moderately correlated with electricity efficiency, with the main outlier in this trend being the 2013/14 season, which had the second lowest production on record but the joint lowest electricity intensity. If this anomalous year is excluded from consideration, then the correlation between production and electricity intensity becomes much stronger. Years where production exceeded 300,000 m3 had an average electricity intensity of approximately 195 kWh/kL, while years where production was less than 200,000 m3 (excluding 2013/14) had an average electricity intensity of 240 kWh/kL, a difference of 40 kWh/kL. At an electricity price of 20.1 c/kWh this is a cost difference of approximately $8.00/kL wine between these seasonal groupings.

Table 6. Electricity intensity by winery size between 2012 and 2022 - kWh/kL wine

Winery size	Total production[a] (kL)	Total electricity use[a] (kWh)	<200k L	200k - 1m L	1m - 4m L	>4m L	Total
Winery category			1	2	3	4	All
Wineries included in the analysis	-	-	46	25	25	24	120
2022	**364,636**	**64,265,400**	**625**	**365**	**295**	**140**	**175**
2021	197,120	48,702,700	690	565	285	190	245
2020	373,200	70,621,200	680	460	265	155	190
2019	394,314	77,850,700	610	425	305	160	195
2018	361,201	81,228,200	505	475	400	180	225
2017	373,009	66,160,300	535	410	285	145	175
2016	263,023	59,762,600	470	500	290	185	225
2015	195,580	44,577,600	480	390	345	170	230
2014	196,424	35,320,900	350	400	310	135	180
2013	255,100	51,020,000	830	410	230	160	200
2012	212,200	55,172,000	740	560	360	180	260

[a] Total production of wineries included in the electricity analysis.

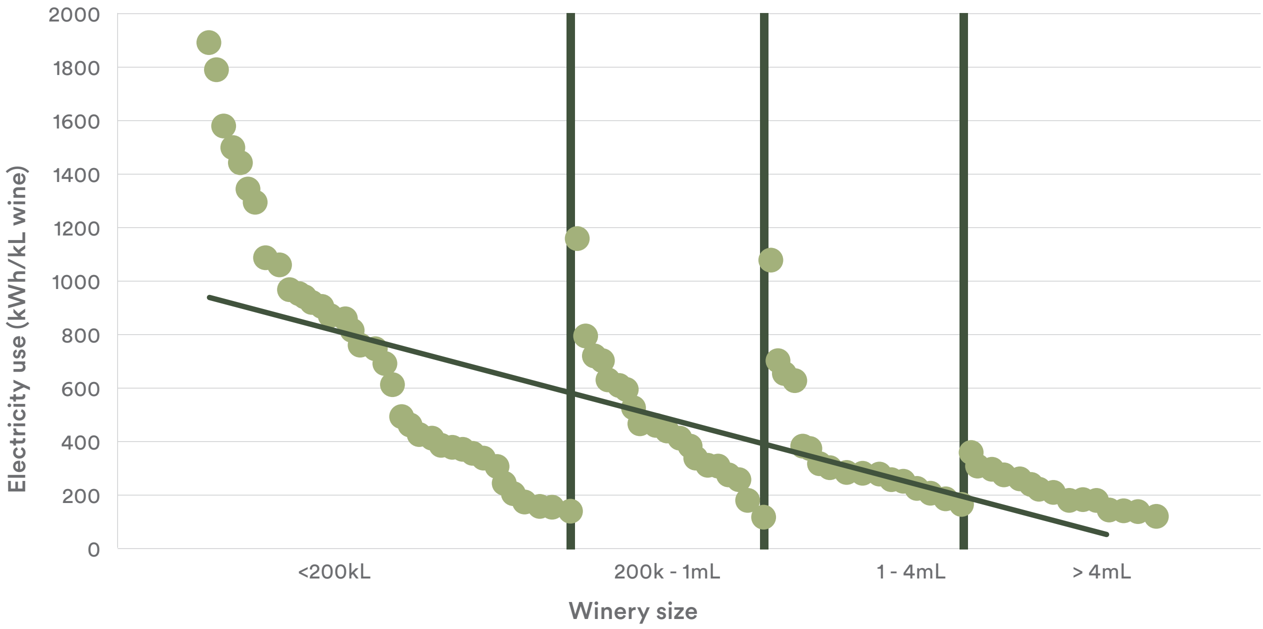


Figure 6. Electricity intensity by winery size

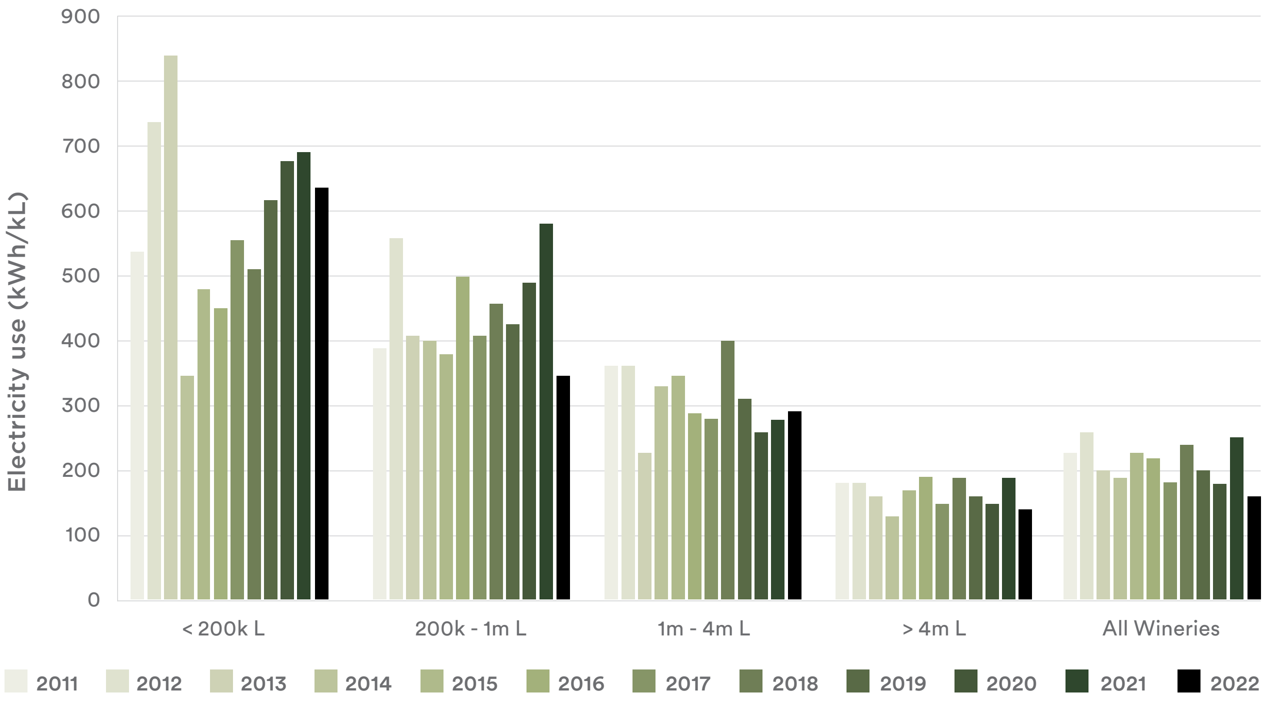


Figure 7. Change in electricity intensity by winery size between 2011 and 2022 vintages

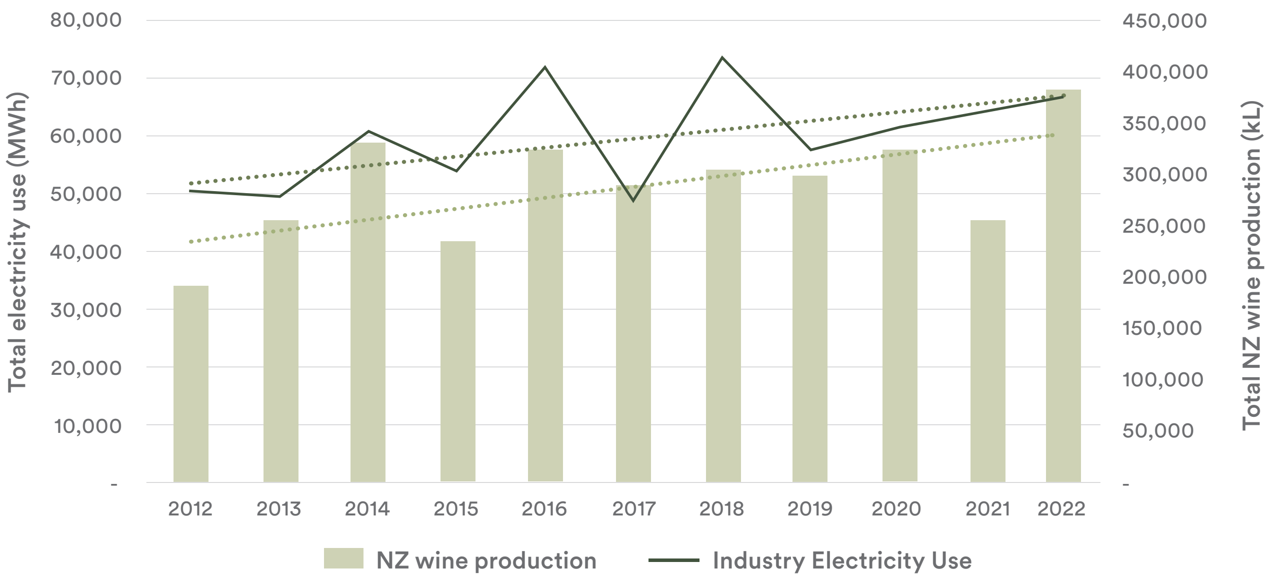


Figure 8. **Total industry electricity use (solid line) compared to total industry production (columns – from NZ Wine Annual Reports) since 2012 and the trend in both (dotted lines)**

Figure 8 uses the industry production data from the NZ Wine Annual Reports to calculate total industry electricity use.

The calculated total electricity use from this vintage was 68,940,000 kWh, comparable to the included questionnaire electricity use of 64,337,000 kWh.

This vintage experienced an increase in total NZ wine industry electricity use when compared to the previous vintage, though due to the far greater production volumes (there was an 85% increase in included production this season based on questionnaire returns, and a 44% increase on total production based on the 2022 Annual Report the overall electricity intensity per unit of wine was far lower.

2.1c Same Site Winery Energy Use Analysis

With such large volumes of data available over the past nine vintages it is possible to compare winery electricity usage across the same sites to see how individual practices and use patterns have changed.

Ninety-five wineries have provided energy use data in both 2021 and 2022 (Table 7), 85% of total included wineries for this season. Amongst these same site wineries production increased by 42%, while total electricity use remained approximately the same, resulting in a 30% decrease in electricity intensity. This compares to the 28% decrease in intensity for all wineries that provided their energy and production data over the same period.

Table 7. Same site winery electricity intensity by winery size between 2021 and 2022 - kWh/kL wine

Winery size	Total production (kL)	Total elec. use (kWh)	< 200k L	200k - 1m L	1m - 4m L	> 4m L	Total
Winery Category			1	2	3	4	All
No. of wineries[a]			36	21	19	19	95
2022	**257,796**	**44,401,800**	**565**	**360**	**240**	**145**	**170**
2021	181,342	44,315,800	635	555	290	190	245

[a] Based on 2022 production extracted from WiSE

Twenty-nine wineries provided data that was included in every vintage between 2014 and 2022, while sixty wineries provided data for every vintage between 2015 and 2022 (Table 8).

As usual, the results from the nine-year period between 2014 and 2022 show considerable variability amongst the same wineries – with this being evident across all categories. Production amongst the same site wineries has increased by approximately 16% (2 year rolling average) between 2014 and 2022. In that time electricity intensity has increased by 7% based on a 2-year rolling average, compared to a 5% increase in electricity intensity from all analysed wineries over the same period.

However, due to the unusually low electricity intensity of the 2014 vintage, this comparison is somewhat misleading. The 2022 season was still among the lowest electricity intensity seasons for this group of wineries, at the joint 3rd lowest intensity over the past nine vintages.

Table 8. Same site winery electricity intensity by winery size[a] between 2014 and 2022 - kWh/kL wine

Winery size	Total production (kL)	Total elec. use (kWh)	< 200k L	200k - 1m L	1m - 4m L	> 4m L	Total
Winery Category			1	2	3	4	All
No. of wineries in 2014 to 2022[a]			6	8	9	6	29
2022	**80,209**	**15,598,920**	**450**	**400**	**200**	**175**	**195**
2021	55,937	15,897,370	515	515	285	235	285
2020	74,385	15,576,120	395	485	225	170	210
2019	65,005	16,180,110	525	535	275	200	250
2018	71,854	15,986,180	505	425	240	190	220
2017	70,647	13,775,030	455	460	295	150	195
2016	71,498	13,707,170	245	375	250	155	190
2015	46,822	13,392,250	500	495	405	155	285
2014	70,699	11,552,710	340	390	215	115	165

[a] The number of wineries in each size category changes between vintages, but the wineries remain the same

2.2 Winery Energy Emissions

Emission factors for electricity change moderately each year, due to weather and other factors influencing electricity generation emissions. The paper *Fuel LCA Emission Factors 2022*[5] was used to calculate life cycle electricity emissions for each vintage using the emissions factor for that year. The 2019 GHG electricity emission factor is the most recent for which data has been made available by the Ministry of Business, Innovation, and Employment (MBIE), and therefore has been applied to the 2019, 2020, 2021 and 2022 vintages. Future updates to the *Fuel LCA Emission Factors* report will enable more recent emission factors to be used next vintage.

The proportion of coal used to generate electricity in New Zealand has increased in recent years, therefore the electricity emission factors used for the most recent seasons will result in an under-estimation. This will be amended in future seasons MBIE continue to release updated data.

Figure 9 shows that, in general, electricity emissions per litre of wine produced have trended downwards, with a 39% reduction since 2011 based on a two-year rolling average (note the comments below about the 2012 year). Total electricity emissions were calculated using the life cycle GHG emissions per litre of wine multiplied by the industry production from the NZ Wine Annual Reports. This year saw a 3% increase in total electricity GHG emissions from last vintage, 9% greater than the 10-year average, but 11% below the high in 2012.

Per litre of wine, this vintage saw a 28% decrease in electricity emissions compared to the 2021 vintage.

The combustion emission factor for electricity, as opposed to the life cycle emission factor used in this report, is approximately 8% lower for NZ's electricity system.

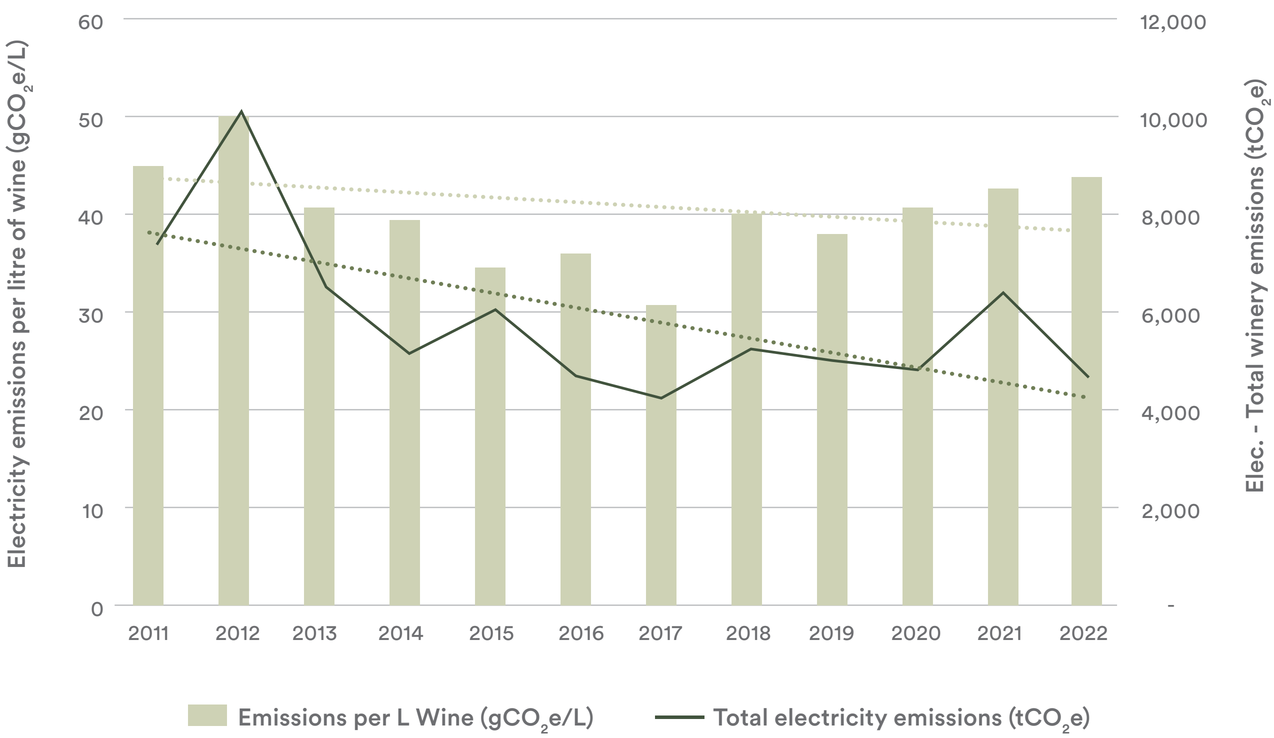


Figure 9. **Life cycle electricity greenhouse gas emissions per litre of wine (solid line) and total winery industry emissions (columns) since 2011 and the trend in both (dotted lines).**

5. Barber, A., and Stenning, H., 2022. New Zealand fuel and electricity total primary energy and life cycle greenhouse gas emission factors 2022. http://agrilink.co.nz/casestudy/life-cycle-assessment-nz-fuel-and-electricity/

The 2012 vintage stands out as having the highest GHG emissions due to that year having both the highest energy use per litre of wine emissions (Figure 9) as well as the highest electricity GHG emission factor. 2012 was an extremely dry year, so consequently there was less hydrogeneration (resulting in a higher electricity emission factor) and greater electricity use in late summer and autumn for wine cooling. Due to the nature of MBIE data reporting, high electricity emission factors will only be applied to electricity usage data several years after first reporting. Therefore, there is the potential that total and per litre emissions for recent years, such as the 2021 and this vintage, will change in future editions of this report.

Despite the low electricity intensity, the significant increase in production has resulted in industry emissions of 8,951 t CO_2e, 10% above the 10-year average of 8,138 t CO_2e. Electricity emissions were 23.4 g CO_2e/L wine or 17.5 g CO_2e/bottle wine, 12% below the 10-year average of 26.7 g CO_2e/L wine (20.0 g CO_2e/bottle).

Using a combustion, rather than life cycle, electricity GHG emission factor of 122.5 g CO_2e/kWh[3] produces electricity emissions of 21.6 g CO_2e/L, with industry emissions of 8,269 t CO_2e in 2022.

A breakdown of emissions by winery size is shown in Table 9. Note that due to revisions in electricity emission data produced by MBIE, and the resultant change in electricity emission factors between each LCA report update, the emissions for each vintage will change slightly between reports.

Table 9. Average winery life cycle electricity emissions (kg $C0_2e$/kL wine) by size since 2011

Winery size	<200k L	200k - 1m L	1m - 4m L	>4m L	Total
Winery Category	1	2	3	4	All
2022	**82.9**	**48.4**	**39.1**	**18.6**	**23.4**
2021	91.5	74.9	32.2	25.2	32.5
2020	90.2	61.0	29.9	20.6	25.2
2019	80.9	56.4	34.4	21.2	25.9
2018	58.3	54.9	44.4	20.8	26.0
2017	65.3	50.1	35.4	17.7	21.4
2016	49.7	52.9	31.9	19.6	23.8
2015	63.6	51.7	45.2	22.5	30.5
2014	48.0	54.8	45.2	18.5	24.7
2013	136.8	67.6	37.7	26.4	33.0
2012	147.0	111.2	70.8	35.7	51.6

Other energy sources used by wineries also contribute to total winery emissions. These energy sources include fossil fuels such as diesel, petrol, LPG, and natural gas.

Natural gas was used by just 8 wineries, with emissions averaging 8.5 kg CO_2e/kL wine, but dropping to an industry average of 0.6 kg CO_2e/kL when all wineries were included (Table 11). LPG was more commonly used, with emissions from its use averaging 6.6 kg CO_2e/kL wine, with the industry average falling slightly to 6.2 kg CO_2e/kL reflecting that most wineries use and record LPG use. Biofuel was not used by any winery based on WiSE Questionnaire returns.

Based on industry production of 383,000 kL wine for the 2022 vintage (New Zealand Wine Annual Report 2022), total industry emissions from winery energy use were 14,696 t CO_2e, with 61% emissions resulting from electricity use.

This amounts to 38.4 g CO_2e/L wine, or 28.8 g CO_2e/bottle from energy use.

Table 10. Fuel use

Energy source	Unit	Number of wineries with included energy source data	Average of those wineries that used the energy source[a] (Unit/kL wine)	Industry average[b] (Unit/kL wine)
Natural gas	MJ	8	140	9.2
LPG	kg	113	2.0	1.9
Diesel	L	98	3.2	2.6
Petrol	L	26	0.3	0.1
Biofuel	L	0	-	-

[a] Total industry energy use divided by total production. The production denominator only includes those wineries that used a specific energy source, i.e., it excludes zeros.

[b] Total industry energy use divided by total production. To be included a winery must provide production as well as energy use data. The denominator includes all wine production irrespective of if a winery used a specific energy source, i.e., it includes zeros.

Table 11. Energy GHG emissions

Emission source	Unit	LCA emission factor[6] (gCO_2e/Unit)	Average of those wineries that used the energy source ($kgCO_2e$/kL wine)	Industry average ($kgCO_2e$/kL wine)
Electricity	kWh	132.6	23.4	23.4
Natural gas	MJ	60.7	8.5	0.6
LPG	kg	3,313	6.6	6.2
Diesel	L	3,147	10.1	8.1
Petrol	L	2,760	0.8	0.1
Biofuel	L	1,750	-	-
Total energy	-	-	-	**38.4**

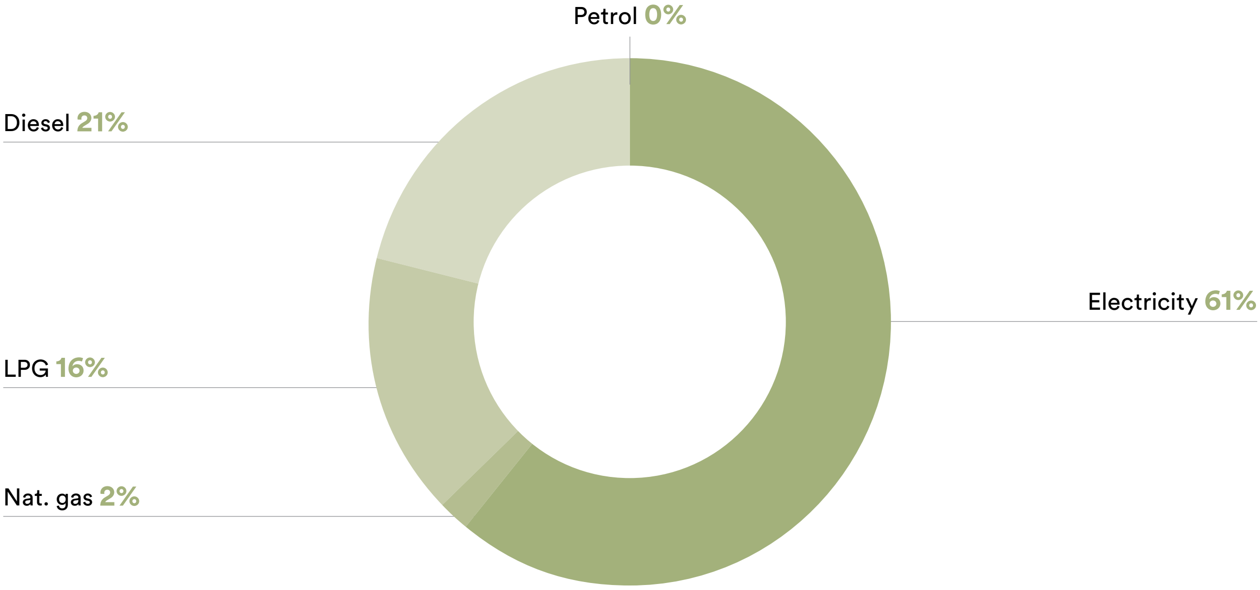


Figure 10. Proportion of GHG emissions from winery energy sources

[6] Barber, A., and Stenning, H., 2022. New Zealand fuel and electricity total primary energy and life cycle greenhouse gas emission factors 2022. http://agrilink.co.nz/casestudy/life-cycle-assessment-nz-fuel-and-electricity/

2.3 Winery Transport Emissions

This season is the first in which transport emissions have been analysed. As such, certain assumptions had to be used when calculating individual emissions. Tables 12 and 13 summarise transport usage by type and transported item, as well as the calculated emissions.

It is anticipated that the calculations for transport emissions, both on an individual and nationally level, will improve in future vintages as exclusion criteria are tightened and calculation methodologies are improved following feedback from this report.

Table 12. Transport use summary

Transport type	Transported unit	Unit[a]	Number of wineries with included transport data	Average of those wineries with transport data (Unit/kL wine)	Industry average (Unit/kL wine)
Truck	Grapes	tkm	96	33.9	25.7
Truck	Bulk Liquid	tkm	60	107.0	72.9
Train	Grapes	tkm	-	-	-
Train	Bulk Liquid	tkm	10	222.8	28.7
Cargo Ship	Grapes	tkm	-	-	-
Cargo Ship	Bulk Liquid	tkm	4	219.4	2.1
Ferry	Grapes	tkm	5	0.9	0.1
Ferry	Bulk Liquid	tkm	24	59.4	22.9

[a] It has been assumed that the density of bulk liquid is 1,000 kg/m^3

Table 13. GHG emissions resulting from transport

Emission source	Transported unit	LCA emission factor (kg CO_2e/t-km)	Average of those wineries with transport data (Unit/kL wine)	Industry average (kg CO_2e/kL wine)
Truck	Grapes	0.28[a]	4.1	3.1
Truck	Bulk Liquid	0.28[a]	11.3	8.5
Train	Grapes	0.03[b]	-	0.0
Train	Bulk Liquid	0.03[b]	7.0	0.9
Cargo Ship	Grapes	0.03[b]	-	0.0
Cargo Ship	Bulk Liquid	0.03[b]	6.9	0.1
Ferry	Grapes	0.06[b]	0.05	0.01
Ferry	Bulk Liquid	0.06[b]	3.5	1.3
Total	**All**	**-**	**32.9**	**14.0**

[a] Dependent on truck RUC type. Range is 0.12 – 0.51 kg CO_2e/tkm. EF's developed by Barber, 2022. Unpublished.

[b] Measuring emissions: a guide for organisations. 2022 detailed guide. Ministry for the Environment.

2.4 Winery Packaging Emissions

As with transport, this season is the first in which packaging emissions have been analysed. It is anticipated that future editions of this report will see moderate revisions to these calculated emissions, as the boundaries of included data tighten and emission factors undergo further refinement.

Emissions from packaging is very affected by the system boundary. We have used the winery door as our system boundary. Therefore, those wineries that package their wine in bottles have their bottle emissions included, while wine distributed in bulk tank for later packaging into bottles does not include the emissions from glass as that occurs further down the supply chain. Further analysis next year will include the development of packaging and transport scenarios in order to help better place into context what is happening beyond the winery door. Nevertheless, the current industry emissions do represent what is happening to the winery door.

Table 14 summarises the packaging used to the winery door, while Table 15 applies a range of packaging emission factors to the packaging.

Table 14. Packaging use summary

Packaging type	Unit	Weight (kg/unit)	Number of wineries with packaging data	Average of those wineries with packaging data[a] (Unit/kL wine)	Industry average (Unit/kL wine)[a]
Regular glass bottle	750ml bottle	0.50	101	250	204
Lightweight glass bottle	750ml bottle	0.30	72	553	358
Refillable bottle	750ml bottle	0.50	-	-	-
Cans	330ml can	0.015	-	-	-
Pouches	1.5L pouch	0.035	-	-	-
Bag in box	3L bag in box	0.179	-	-	-
Kegs	G20L keg	6.0	10	0.04	0.00
Flexitank	Flexitank	40.3	24	0.01	0.01

[a] Usage was excluded if greater than 2,500 bottles/cans per kL, 200 kegs/kL, or 10 Flexitanks/kL.

Table 15. GHG emissions resulting from packaging

Packaging type	Unit	LCA emission factor (kg CO_2e/unit)	Average of those wineries with packaging data[a] (kg CO_2e/kL wine)	Industry average (kg CO_2e/kL wine)
Regular glass bottle	kg	0.625[a]	90.5	74.0
Lightweight glass bottle	kg	0.625[a]	120.3	77.8
Refillable bottle	kg	0.625[a]	0.0	0.0
Cans	kg	-	0.0	0.0
Pouches	Pouch	-	0.0	0.0
Bag in box	Bag in box	-	0.0	0.0
Kegs	kg	3.89	1.0	0.0
Flexitank	kg	2.15[b]	1.0	0.5
Total	-	-		**152.3**

[a] McLaren S., Clothier B., Barber A., McNally S., Bullen L., Mazzetto A., Ledgard S., 2021. Updating The Carbon Footprints for Selected New Zealand Agricultural Products - an update for apples, kiwifruit and wine. Prepared for Ministry for Primary Industries. https://www.mpi.govt.nz/dmsdocument/51079-Updating-the-carbon-footprint-for-selected-New-Zealand-agricultural-products-an-update-for-apples-kiwifruit-and-wine

[b] Calculated by the authors based on the quantity of polyethylene and polypropylene.

2.5 Total Winery GHG Emissions

Total estimated winery emissions for the 2022 vintage were 78,389 t CO_2e. Using NZ wine Annual Report 2022 production volumes, winery activities contribute 204.7 g CO_2e/L produced by the industry, or 153.5 g CO_2e/bottle. Table 16 provides a detailed breakdown of the industry's winery GHG emissions, to the winery door, by emission source.

Packaging accounts for 74% of total winery emissions, with electricity usage and transportation of grapes and bulk liquid accounting for over two-thirds of the remaining emissions.

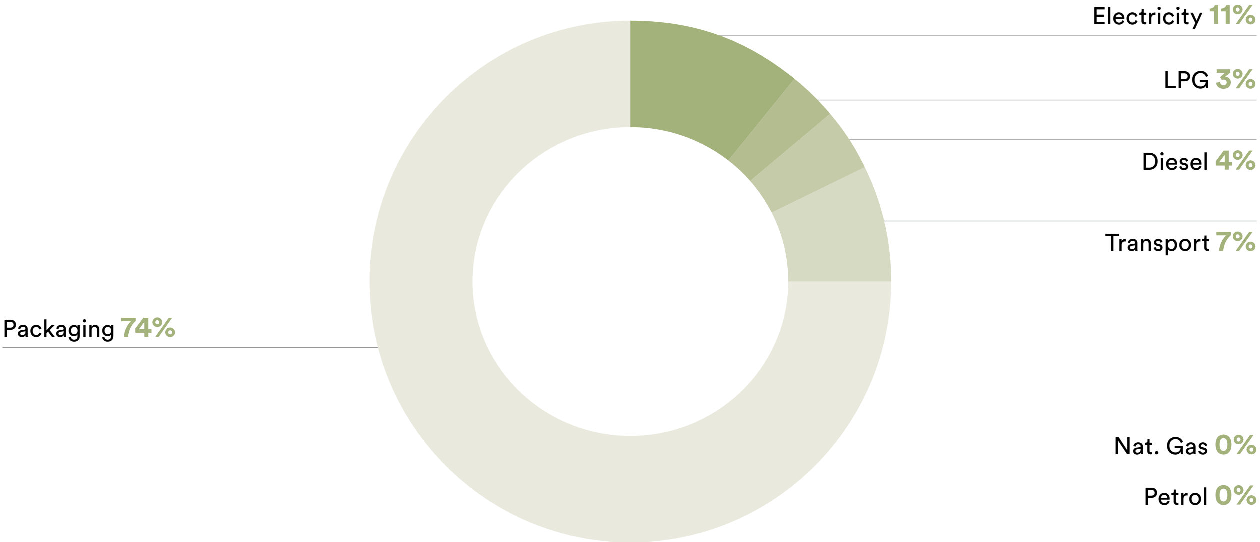


Figure 11. **Proportion of GHG emissions from winery activites.**

Table 16. Winery GHG emissions summary

Category	GHG emissions (kg CO_2e/kL wine)		Industry GHG emissions (t CO_2e)	
	2021[a]	2022	2021[a]	2022
Total	**216.9**	**204.7**	**57,782**	**78,389**
Energy	50.6	38.4	13,475	14,633
Diesel	12.7	8.1	3,381	3,111
Petrol	0.3	0.1	66	55
Electricity	32.5	23.4	8,655	8,888
LPG	4.7	6.2	1,257	2,366
Natural gas	0.4	0.6	116	213
Transport	(14.0)[a]	14.0	(5,362)[a]	5,362
Packaging	(152.3)[a]	152.3	(58,331)[a]	58,331

[a] Transport and packaging emissions were not analysed in the previous season. Therefore, the total emissions in 2021 use the transport and packaging emissions for the 2022 vintage.

3.0 Total Wine Industry GHG Emissions

Total GHG emissions from the sources analysed in this report were 131,765 t CO_2e for the 2022 vintage. This equates to 248 kg CO_2e/tonne grapes, or 344 g CO_2e/L wine. Per bottle of wine emissions from vineyard and winery production are approximately 258 g CO_2e/bottle. When the largest source of uncertainty – packaging – is removed from the calculated emissions they fall to just 73,437 t CO_2e or 144 g CO_2e/bottle.

The two largest sources of emissions are winery packaging (accounting for 44% of total wine production emissions) and vineyard fossil fuel use (accounting for 24%). These represent the biggest opportunities for emissions reductions in the wine sector, with reductions in wine packaging, changes to packaging, switching to more fuel-efficient machinery, reducing machinery passes, and electrification where possible being a selection of mitigations that may help reduce the carbon footprint of the industry.

Other opportunities to lower emissions include increasing the proportion of the agrichemical programme using products with lower embodied emissions (e.g., reducing the use of synthetic fungicides, insecticides, and herbicides).

Reducing the proportion of grapes and bulk liquid transported by truck and increasing the proportion transported by train or ship will also reduce emissions resulting from transport.

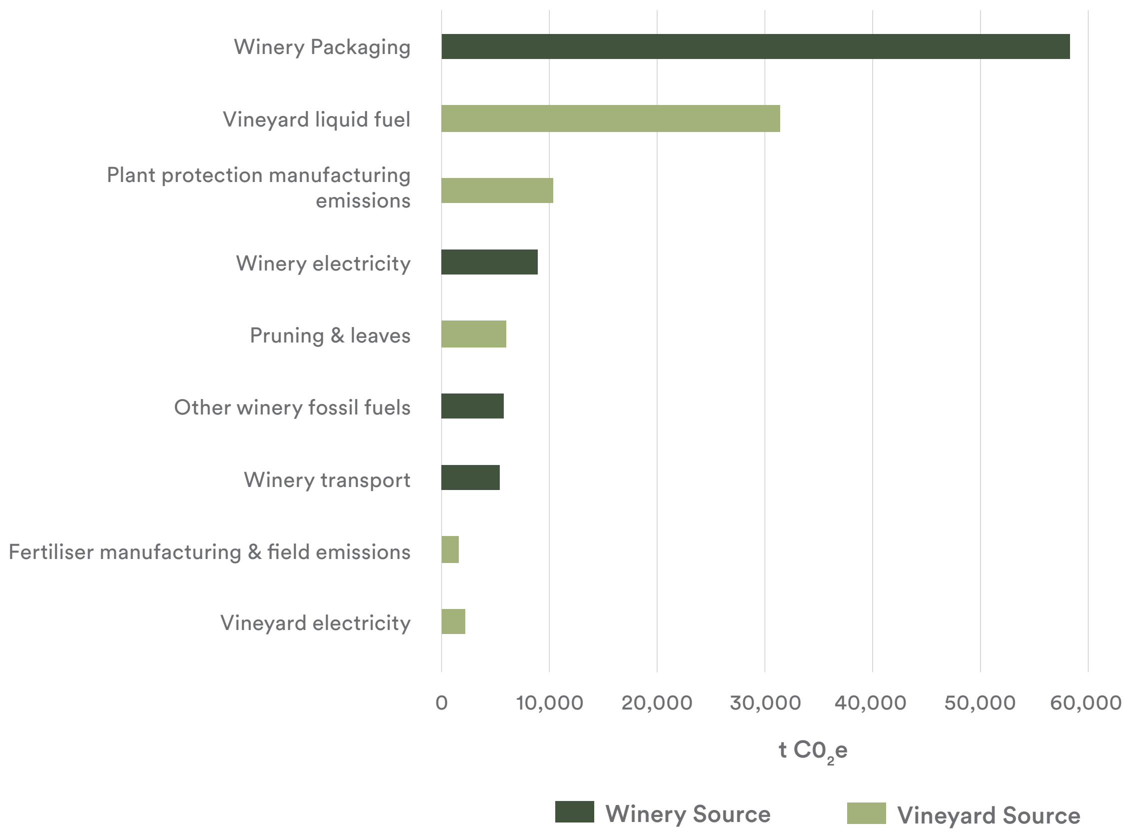


Figure 12. **Total industry GHG emissions by source. Winery emission sources are in dark green and vineyard emission sources are in light green**

4.0 Narrative Data

Narrative data from the WiSE Questionnaire can be used to build a more holistic picture on vineyard and winery practices that pure resource usage data cannot always show.

These practices can include initiatives such as biodiversity plantings, recycling schemes, and the installation of energy reduction devices.

In future seasons there is the potential to start analysing how operation's management practices are reflected in the resource usage data and resultant emissions.

4.1 Vineyard questionnaire reponses

The WiSE Vineyard Questionnaire contains a question on carbon footprint mitigation initiatives.

The response to this question shows that there is significant potential for the expansion of emissions reduction initiatives on vineyards.

Figure 13 shows the breakdown of responses, with nearly half of vineyards indicating they had no initiatives in place or otherwise not responding to the question.

The most popular initiative is equipment upgrades to improve efficiency and therefore reduce fuel use (28%), followed by energy efficiency initiatives such as sensors, timers, staff training (22%). Sixteen percent of vineyards have also instituted energy management plans.

Renewable energy is utilised by a small portion of vineyards, with the most popular type being solar panels (7%), followed by wind turbines (2%).

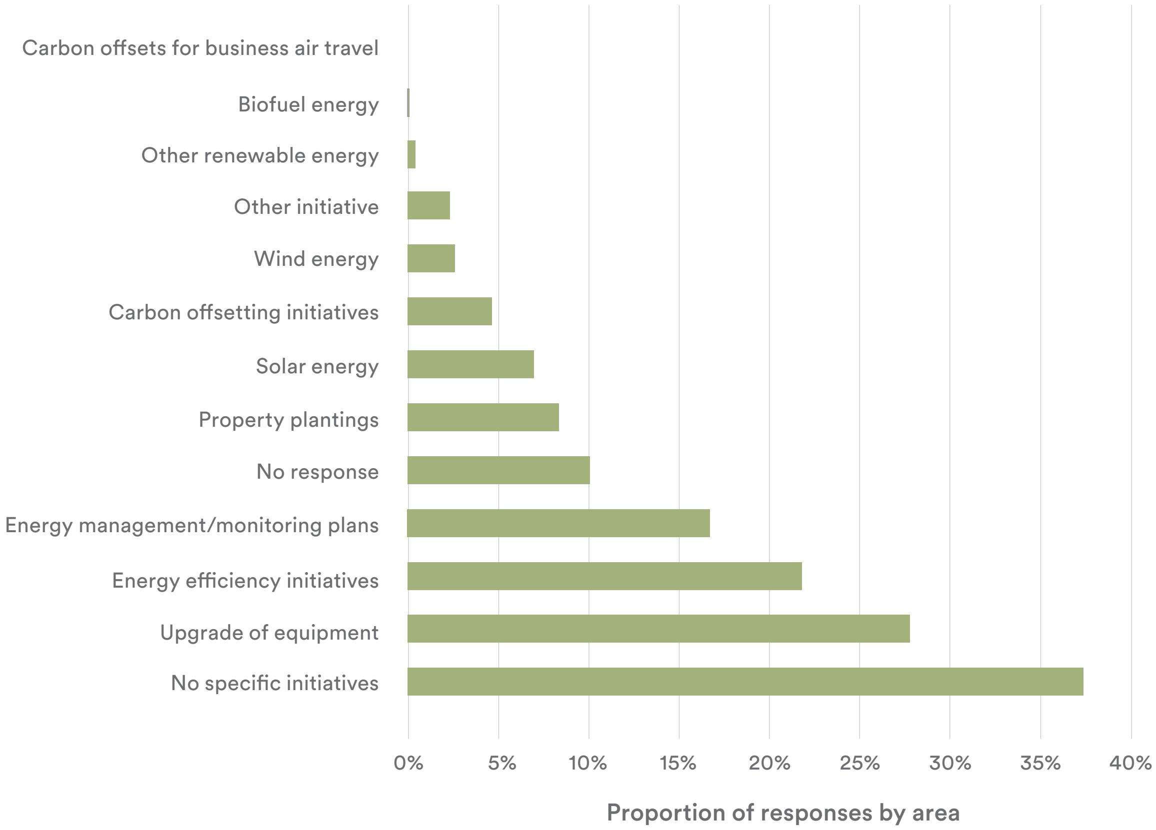
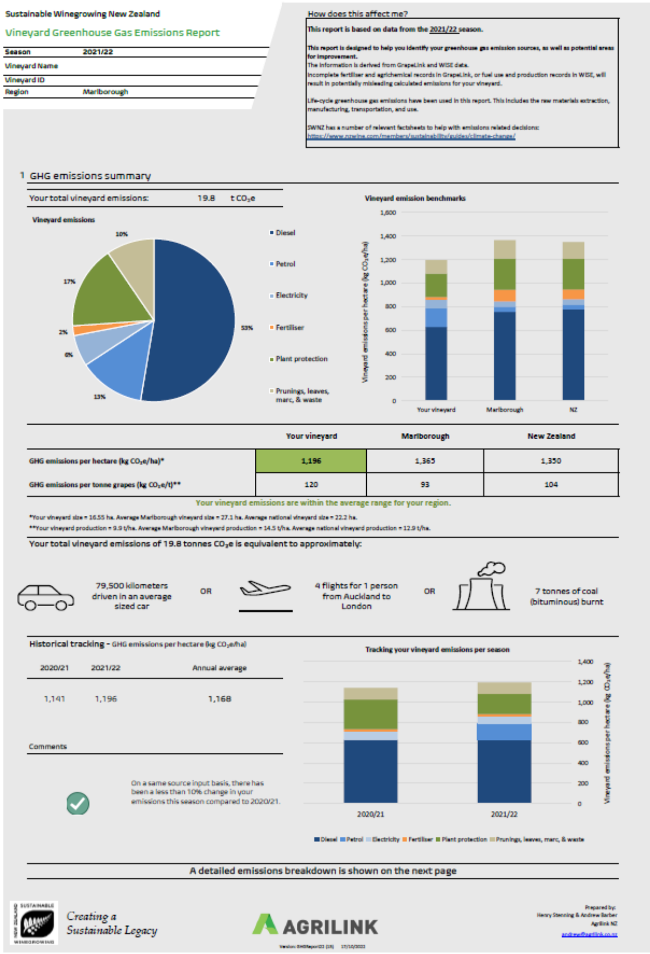


Figure 13. **Emissions mitigations initiatives by respondent area from the WiSE questionnaire.**

Appendix 1. Individualised Report Examples

Individualised Report Examples

This season was the second for which an individualised vineyard GHG emission benchmarking report was prepared. This report provided an individualised carbon footprint for each vineyard in the SWNZ programme, using GrapeLink spray diary plant protection and fertiliser data, and WiSE Questionnaire energy use data. Individual emissions profiles were compared to regional and industry averages. This season the report was enhanced significantly, with new metrics and an overhauled presentation.



Sustainable Winegrowing New Zealand

Vineyard Greenhouse Gas Emissions Report

Season	2021/22
Vineyard Name	
Vineyard ID	
Region	Marlborough

How does this affect me?

This report is based on data from the 2021/22 season.

This report is designed to help you identify your greenhouse gas emission sources, as well as potential areas for improvement.
The information is derived from GrapeLink and WISE data.
Incomplete fertiliser and agrichemical records in GrapeLink, or fuel use and production records in WISE, will result in potentially misleading calculated emissions for your vineyard.

Life-cycle greenhouse gas emissions have been used in this report. This includes the raw materials extraction, manufacturing, transportation, and use.

SWNZ has a number of relevant factsheets to help with emissions related decisions:
https://www.nzwine.com/members/sustainability/guides/climate-change/

1 GHG emissions summary

Your total vineyard emissions: 19.8 t CO_2e

	Your vineyard	Marlborough	New Zealand
GHG emissions per hectare (kg CO_2e/ha)*	1,196	1,365	1,350
GHG emissions per tonne grapes (kg CO_2e/t)**	120	93	104

Your vineyard emissions are within the average range for your region.

*Your vineyard size = 16.55 ha. Average Marlborough vineyard size = 27.1 ha. Average national vineyard size = 22.2 ha.
**Your vineyard production = 9.9 t/ha. Average Marlborough vineyard production = 14.5 t/ha. Average national vineyard production = 12.9 t/ha.

Your total vineyard emissions of 19.8 tonnes CO_2e is equivalent to approximately:

79,500 kilometers driven in an average sized car OR 4 flights for 1 person from Auckland to London OR 7 tonnes of coal (bituminous) burnt

Historical tracking - GHG emissions per hectare (kg CO_2e/ha)

2020/21	2021/22	Annual average
1,141	1,196	1,168

Comments

On a same source input basis, there has been a less than 10% change in your emissions this season compared to 2020/21.

A detailed emissions breakdown is shown on the next page

Creating a Sustainable Legacy

AGRILINK

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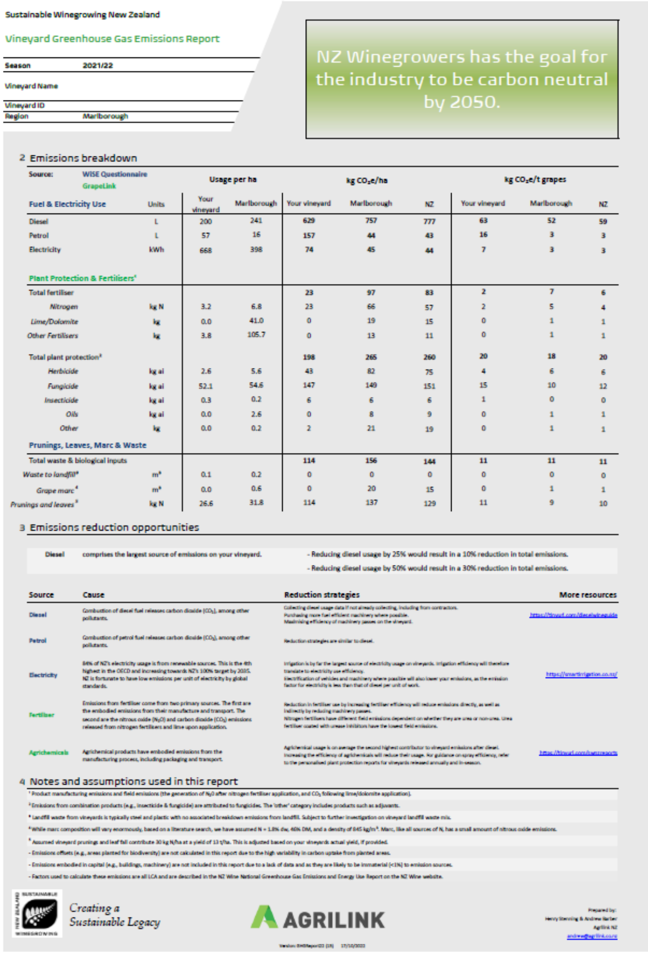

Sustainable Winegrowing New Zealand

Vineyard Greenhouse Gas Emissions Report

Season	2021/22
Vineyard Name	
Vineyard ID	
Region	Marlborough

NZ Winegrowers has the goal for the industry to be carbon neutral by 2050.

2 Emissions breakdown

Source: WISE Questionnaire, GrapeLink

	Units	Usage per ha: Your vineyard	Usage per ha: Marlborough	kg CO_2e/ha: Your vineyard	kg CO_2e/ha: Marlborough	kg CO_2e/ha: NZ	kg CO_2e/t grapes: Your vineyard	kg CO_2e/t grapes: Marlborough	kg CO_2e/t grapes: NZ
Fuel & Electricity Use									
Diesel	L	200	241	629	757	777	63	52	59
Petrol	L	57	16	157	44	43	16	3	3
Electricity	kWh	668	398	74	45	44	7	3	3
Plant Protection & Fertilisers[1]									
Total fertiliser				23	97	83	2	7	6
Nitrogen	kg N	3.2	6.8	23	66	57	2	5	4
Lime/Dolomite	kg	0.0	41.0	0	19	15	0	1	1
Other Fertilisers	kg	3.8	105.7	0	13	11	0	1	1
Total plant protection[2]				198	265	260	20	18	20
Herbicide	kg ai	2.6	5.6	43	82	75	4	6	6
Fungicide	kg ai	52.1	54.6	147	149	151	15	10	12
Insecticide	kg ai	0.3	0.2	6	6	6	1	0	0
Oils	kg ai	0.0	2.6	0	8	9	0	1	1
Other	kg	0.0	0.2	2	21	19	0	1	1
Prunings, Leaves, Marc & Waste									
Total waste & biological inputs				114	156	144	11	11	11
Waste to landfill[3]	m^3	0.1	0.2	0	0	0	0	0	0
Grape marc[4]	m^3	0.0	0.6	0	20	15	0	1	1
Prunings and leaves[5]	kg N	26.6	31.8	114	137	129	11	9	10

3 Emissions reduction opportunities

Diesel comprises the largest source of emissions on your vineyard.
- Reducing diesel usage by 25% would result in a 10% reduction in total emissions.
- Reducing diesel usage by 50% would result in a 30% reduction in total emissions.

Source	Cause	Reduction strategies	More resources
Diesel	Combustion of diesel fuel releases carbon dioxide (CO_2), among other pollutants.	Collecting diesel usage data if not already collecting, including from contractors. Purchasing more fuel efficient machinery where possible. Maximising efficiency of machinery passes on the vineyard.	https://tinyurl.com/dieselwineguide
Petrol	Combustion of petrol fuel releases carbon dioxide (CO_2), among other pollutants.	Reduction strategies are similar to diesel.	
Electricity	84% of NZ's electricity usage is from renewable sources. This is the 4th highest in the OECD and increasing towards NZ's 100% target by 2035. NZ is fortunate to have low emissions per unit of electricity by global standards.	Irrigation is by far the largest source of electricity usage on vineyards. Irrigation efficiency will therefore translate to electricity use efficiency. Electrification of vehicles and machinery where possible will also lower your emissions, as the emission factor for electricity is less than that of diesel per unit of work.	https://smartirrigation.co.nz/
Fertiliser	Emissions from fertiliser come from two primary sources. The first are the embodied emissions from their manufacture and transport. The second are the nitrous oxide (N_2O) and carbon dioxide (CO_2) emissions released from nitrogen fertilisers and lime upon application.	Reduction in fertiliser use by increasing fertiliser efficiency will reduce emissions directly, as well as indirectly by reducing machinery passes. Nitrogen fertilisers have different field emissions dependent on whether they are urea or non-urea. Urea fertiliser coated with urease inhibitors have the lowest field emissions.	
Agrichemicals	Agrichemical products have embodied emissions from the manufacturing process, including packaging and transport.	Agrichemical usage is on average the second highest contributor to vineyard emissions after diesel. Increasing the efficiency of agrichemicals will reduce their usage. For guidance on spray efficiency, refer to the personalised plant protection reports for vineyards released annually and in-season.	https://tinyurl.com/swnzreports

4 Notes and assumptions used in this report

[1] Product manufacturing emissions and field emissions (the generation of N_2O after nitrogen fertiliser application, and CO_2 following lime/dolomite application).
[2] Emissions from combination products (e.g., insecticide & fungicide) are attributed to fungicides. The 'other' category includes products such as adjuvants.
[3] Landfill waste from vineyards is typically steel and plastic with no associated breakdown emissions from landfill. Subject to further investigation on vineyard landfill waste mix.
[4] While marc composition will vary enormously, based on a literature search, we have assumed N = 1.8% dw, 40% DM, and a density of 845 kg/m³. Marc, like all sources of N, has a small amount of nitrous oxide emissions.
[5] Assumed vineyard prunings and leaf fall contribute 30 kg N/ha at a yield of 13 t/ha. This is adjusted based on your vineyards actual yield, if provided.
- Emissions offsets (e.g., areas planted for biodiversity) are not calculated in this report due to the high variability in carbon uptake from planted areas.
- Emissions embodied in capital (e.g., buildings, machinery) are not included in this report due to a lack of data and as they are likely to be immaterial (<1%) to emission sources.
- Factors used to calculate these emissions are all LCA and are described in the NZ Wine National Greenhouse Gas Emissions and Energy Use Report on the NZ Wine website.

Creating a Sustainable Legacy

AGRILINK

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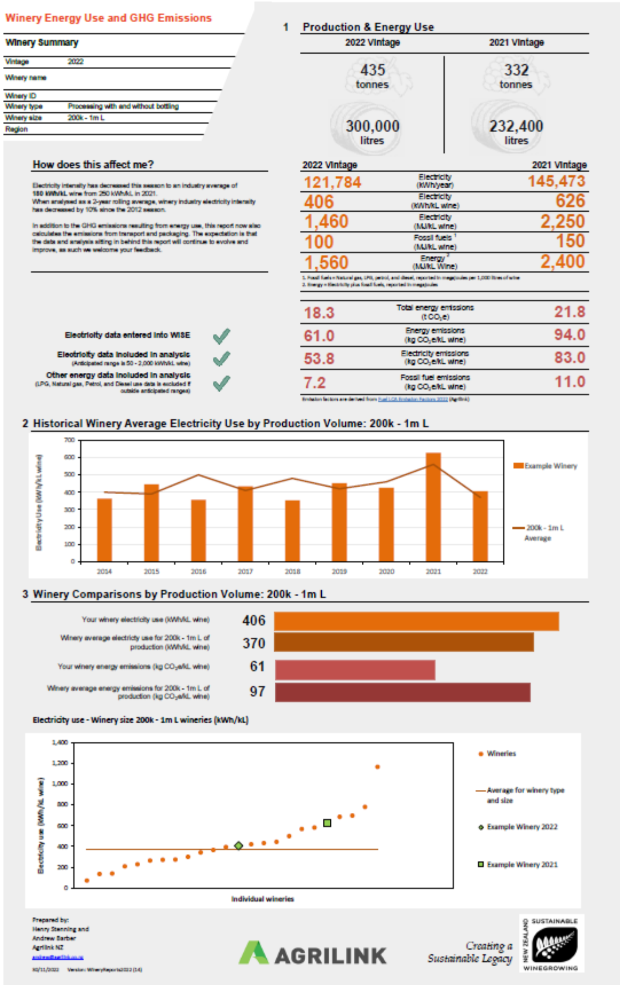
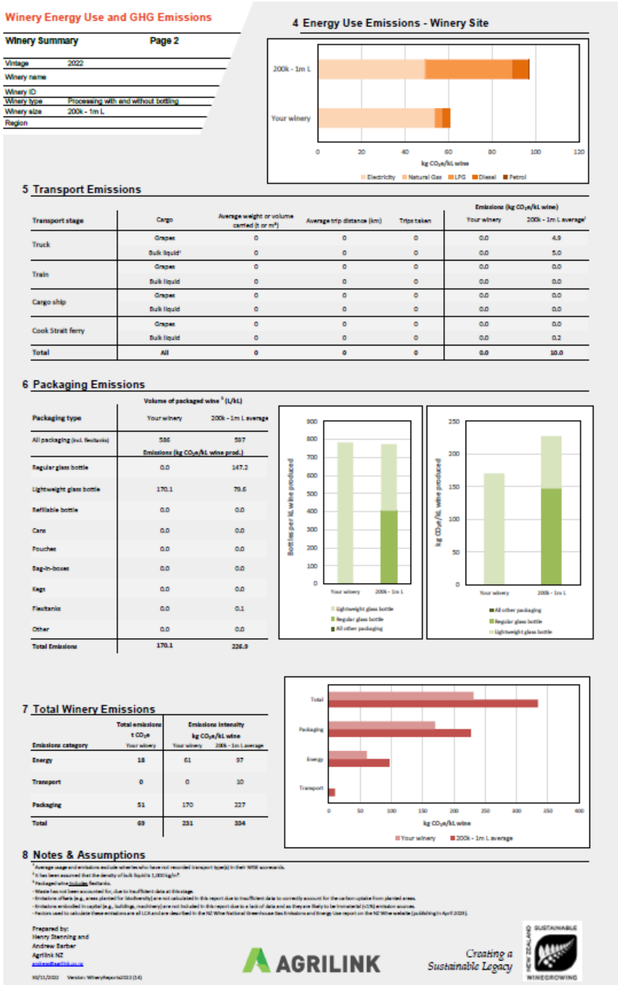
The following is an example of the individualised winery GHG benchmarking report. All Sustainable Winegrowing NZ winery members, who completed a 20212Questionnaire, received an individualised report. 172 were prepared, including those who did not complete the energy section of their Questionnaire but excluding bottling only wineries. This season this report was enhanced significantly, to include emissions from transport and packaging, thereby transforming it from an energy only report to a more comprehensive GHG report.





Appendix 2. Plant Protection Emission Factors and Methodology

GHG emissions for the production, formulation, packaging, and transport to NZ of plant protection products can be an important component in horticultural carbon footprinting. Previous studies in apples (Hume et al., 2009), kiwifruit (Mithraratne et al., 2010), and wine (Greenhalgh et al., 2008) found that plant protection products accounted for 12%, 4%, and 20% respectively of total orchard and vineyard emissions.

The primary energy of these products was determined by Green (1987) and later turned into carbon dioxide emission factors by Wells (2001) and Saunders et al. (2006). Sutter (2010) produced a comprehensive report on pesticide manufacture, which included primary energy use and an inventory of emissions. Müller et al. (2011) drew on all these reports, and they conducted their own research to determine GHG emissions for three pesticide products delivered to NZ.

Müller et al (2011) found that the contribution of transport, packaging, and formulation to the total GHG emission for the imported and formulated products ranged between 9% and 31%. It was highest for the herbicide (31%), and lowest for fungicide (9%).

Following discussions with Müller (pers. comm 26/11/21) it was determined that the total emissions in Table 2 of their 2011 report were emissions per kilogram of active ingredient rather than per kilogram of formulated product. The values per kilogram of formulated product are shown in Table A2-2 below.

The results from the Müller et al. (2011) study is summarised in Table A2-1 with the correction to the total emissions denominator. The emissions for formulation, packaging, and transport to NZ has been calculated per kilogram of formulated product (Table A2-2).

Table A2-1. Pesticide GHG Emissions (kg CO_2e)

	Manufacturing emissions [a]	Total emissions [b]	Formulation, packaging, and transport to NZ		Active ingredient (ai) %	Formulation, packaging, and transport to NZ
	Emissions per kg ai (A)	Per kg ai (B)	Per kg ai (C) (C = B - A)	% of total	(D)	Emission per kg formulated pesticide (C x D)
Glyphosate (herbicide)	10.12	14.74	4.62	31.3%	0.36	1.66
Iprodione (fungicide)	15.72	17.37	1.65	9.5%	0.75	1.24
Thiacloprid (insecticide)	16.00	19.17	3.17	16.5%	0.48	1.52
Average	13.9	17.1	3.1	-	-	1.5

[a] Müller et al. (2011) Table 1

[b] Müller et al. (2011) Table 2 corrected to emissions per kg ai – pers. comm. Müller 26/11/21.

Table A2-2. **Pesticide GHG emissions per kilogram of formulated product (kg CO_2e/kg product)**

	Manufacturing [a]	Formulation, packaging, and transport to NZ	Active ingredient (ai) %	Total emissions
	Emissions per kg ai (A)	Emission per kg formulated pesticide (B)	(C)	Emission per kg formulated pesticide (A x C + B)
Glyphosate (herbicide)	10.12	1.66	0.36	5.3
Iprodione (fungicide)	15.72	1.24	0.75	13.0
Thiacloprid (insecticide)	16.00	1.52	0.48	9.2
Average	13.9	1.5	-	-

[a] Müller et al. (2011) Table 1

To determine the emission factor of pesticides the equation is:

> Total GHG emissions per kg of product = (manufacturing emissions per kg ai x % ai) + formulation, packaging, and transport to NZ per kg formulated product.

The first part of this equation calculates the amount of active in 1kg of product and the associated emissions for that kg.

As an example, the herbicide Lion 490 with 490 g glyphosate/L has GHG emissions of: (10.12 * 0.49) + 1.66 = 6.6 kg CO_2e/L.

Sutter (2010) presented the cumulative energy demand (CED) for a range of specific pesticides and pesticide groups. This range between just under 100 to just over 400 MJ/kg ai. If the GHG emission factor for diesel is used to represent fossil fuel emissions (0.068 kg CO_2e/MJe) and this is multiplied by the energy values, then manufacturing emissions range between 6.8 to 27.2 kg CO_2e/kg ai.

The Müller et al. (2011) manufacturing results fall within this range. Sutter (2010) found that individual chemicals range between approximately 75 to 560 MJe/kg ai or 5.1 to 38.1 kg CO_2e/kg ai (assuming 0.068 kg CO_2e/MJe). Glyphosate had an energy value of approximately 210 MJe/kg ai or 14.3 kg CO_2e/kg ai. This is just over 40% higher than the Müller et al. (2011) result.

While further analysis would improve the accuracy of these pesticide emission factors, they are nevertheless based on a considerable amount of analysis and are specific to New Zealand.

Broadly speaking, pesticide emissions can be calculated using the emission factors shown in Table A2-3. Manufacturing emissions are based on the emissions per kg of ai and then converted into emissions per kg of formulated pesticide. Formulation, packaging, and transport emissions are determined based on the emissions per kg of formulated product. The quantity of each product recorded in the grower's spray diary is then classified by product type and multiplied by the appropriate emission factor.

Table A2-3. **Pesticide GHG emissions (kg CO_2e) by product type**

Product type	Manufacturing energy	Manufacturing Emissions	Formulation, packaging, and transport to NZ
	MJe/kg ai	kg CO_2e/kg ai	kg CO_2e/kg formulated pesticide
Herbicide		10.1	1.7
Fungicide		15.7	1.2
Insecticide		16.0	1.5
Fungicide inorganic (CU and S)	5 [a]	0.3	1.2
Oil	9 [a]	0.6	1.5
Adjuvants	10	0.7	1.5
Plant growth regulators (PGR)	87 [a]	5.9	1.5
Hydrogen cyanimide	87 [b]	5.9	1.5
Bacillus thuringiensis	77 [c]	5.2	1.5
Other organic products	10	0.7	1.5

[a] Mithraratne et al., 2010

[b] Barber A. and Benge J., 2006

[c] Milà i Canals, 2003.

References

Barber, A., Benge, J. 2006. Total energy indicators: benchmarking green, green organic and gold kiwifruit orchards. ARGOS Report No. 06/08. Pukekohe, The AgriBusiness Group.

Green, M. 1987. Energy in pesticide manufacture, distribution and use. In: Helsel ZR ed. Energy in plant nutrition and pest control. Amsterdam, Elsevier.

Greenhalgh, S., Mithraratne, N., Sinclair, R., Smith, A., McConachy, E., and Barber, A. 2008. GHG Product Accounting Guidelines for the Wine Industry (No. LC0809/036). Auckland, New Zealand: Landcare Research

Hume, A., Barber, A., East, A., McLaren, S., Deurer, M., Clothier, B., and Palmer, J. 2009. Carbon footprinting for the apple supply chain – methodology and scoping study. Landcare Research Contract Report: LC0809/174.

McLaren S., Clothier B., Barber A., McNally S., Bullen L., Mazzetto A., Ledgard S., 2021. Updating The Carbon Footprints for Selected New Zealand Agricultural Products - an update for apples, kiwifruit and wine. Prepared for Ministry for Primary Industries. https://www.mpi.govt.nz/dmsdocument/51079-Updating-the-carbon-footprint-for-selected-New-Zealand-agricultural-products-an-update-for-apples-kiwifruit-and-wine

Milà i Canals L. 2003. Contribution to LCA methodology for agricultural systems: site-dependency and soil degradation impact assessment. Doctoral thesis. Barcelona, Universitat Autònoma de Barcelona.

Mithraratne, N., Barber, A., and McLaren, S. J. 2010. Carbon Footprinting for the Kiwifruit Supply Chain – Report on Methodology and Scoping Study. Prepared for Ministry of Agriculture and Forestry.

Müller, K., Deurer, M., and Clothier, BE. 2011. An ILCD database of three pesticides for the Kiwifruit industry. Prepared for The NZLCM Centre.

Saunders C, Barber A, Taylor G. 2006. Food miles: comparative energy/emissions performance of New Zealand's agricultural industry. Report No. 285. Prepared for Ministry of Foreign Affairs and Trade. Lincoln, Canterbury, Agribusiness and Economic Research Unit, Lincoln University.

Sutter, J. 2010. Life Cycle Inventories of Pesticides. Data V2.2. Swiss Centre for Life Cycle Inventories. https://www.researchgate.net/publication/313056011_Life_Cycle_Inventories_of_Pesticides_Data_v22_2010

Wells, C. 2001. Total energy indicators of agricultural sustainability: dairy farming case study final report. Report to MAF Policy by Department of Physics, University of Otago.