

GHG emission assessment methodology for the YEN Zero pilot year

This document sets out the approach that ADAS is using to calculate the greenhouse gas (GHG) emissions for each field within the pilot year of YEN Zero. There are three types of emissions that this assessment will capture:

1. Embedded emissions – the emissions resulting from the production and transport (up to farm gate) of the inputs required for that field
2. On-farm energy use – the emissions resulting from on-farm fuel use for operations required for that field
3. Field emissions – the emissions resulting from the application of synthetic and organic nitrogen fertiliser and return of crop residues to the field

These are described in detail below with the key emission factors (value which converts an activity into equivalent CO₂ emissions) for embedded emissions and on-farm energy use presented in Table 2.

Embedded emissions

Embedded emissions for three categories of input are included in the assessment: seed, fertiliser, and agrochemicals.

1. Embedded emissions in seed sown (kg/ha): Seed inputs will have associated embedded emissions from their production. Average emissions for seed are taken from the European Commission's JEC E3-database. Only reference sources for wheat, OSR and maize are available for embedded seed emissions. Consequently, for crops other than OSR and maize, embedded wheat seed emissions were assumed.
2. Manufacture of fertilisers: ammonium nitrate (AN), urea, liquid urea ammonium nitrate (UAN), phosphate (P₂O₅), potash (K₂O), and lime (expressed per kg of nutrient). Note that an individual emission factor for sulphate is not available; sulphate-containing fertilisers use sulphuric acid, which is produced using waste heat from other manufacturing processes so is assumed to have no emissions. The embedded emission figures given in Table 2 are based on European production; these emissions can be higher for fertiliser produced elsewhere. These European figures will be used as default values. For urea and UAN, emissions from urea hydrolysis are included in the manufacture emissions (stated in Table 2).

If entrants provide information on their fertilisers that enables identification of other production regions, the relevant embedded emissions for that region will be used instead. Additionally, if a fertiliser manufacturer has published an accredited carbon footprint figure, then this value will be used instead of the reference source given in Table 2. For lime applications it is assumed all products have the same manufacture emissions, therefore an emission factor for kg of product is used (Table 2). The calculated emissions for lime are divided by 4 as YEN Zero entrants are asked for quantity of lime applied in the last 4 years.

a. Relevant accredited fertiliser manufacture C footprints used include:

- i. Those manufactured by CF Fertilisers, [published here](#)
- ii. Those manufactured/distributed by Origin Fertilisers where C footprints can be sourced using the NUTRI-CO₂OL tool

In this assessment, organic fertilisers (e.g., manure) are assumed to have no embedded emissions, which is consistent with other crop carbon footprinting methodologies.

3. Manufacture of agrochemicals: fungicide, herbicide, insecticide, and plant growth regulators (PGRs). The CO₂e emissions associated with the manufacture of agrochemicals is based on the number of applications made. Standard figures of kg of ai in each application of each agrochemical type (herbicide, fungicide, PGR, and insecticide) were estimated based on data from the Defra Pesticide Usage Survey (Garthwaite et al., 2020). The statistics of weight of active ingredient (ai) and the area treated (ha) were used to calculate average kg ai/ha for each application. An emission factor was then used to convert kg of ai/ha into kg CO₂e/ha (Table 2). The emission factor for PGRs (kg CO₂e/kg ai) was assumed to be the same as herbicides as no data could be found from the pesticide manufacture reference source.

On-farm energy use

For calculating emissions from on-farm energy use, we are interested in the amount of fuel used for field operations and grain drying. Participants supplied information on these either by providing the actual fuel use, if it was measured, or by providing a list of farming operations that were conducted for each field. These operations are cultivations, sprayer and fertiliser passes, harvesting, and baling straw.

For this we are using the latest dataset from [BEIS \(2021\)](#). This includes emission factors for the use of Diesel (*100% mineral diesel, not blended with biofuel*), both for its use and for the emissions associated with its extraction, refining and transportation (the *well-to-tank* emissions).

- 2.706 kg CO₂e/litre (use)
- 0.629 kg CO₂e/litre (production)
- Total emissions: 3.334 kg CO₂e/litre (total emissions)

Fuel provided by entrants was not used to calculate emissions from operations due to the disparity between the two methods and not all entries providing fuel use figures. Instead, the energy requirements for each field operation were used to calculate emissions from operations, listed in Table 2. Where entrants have detailed cultivation strategy as ‘deep non-inversion’, a sum of ‘drill’, ‘roll’, and ‘disc’ is used. These energy requirements are based on figures from Williams et al. (2006). Soil texture was not considered when calculating energy use; all sites were assumed to be of a loam soil. Emissions are calculated using the above emission factor assuming there are 38 MJ/l diesel, which gives 0.0877 kg CO₂e/MJ.

Emissions associated with grain drying are calculated based on the amount of material being dried, the starting moisture content and final moisture content. The energy required for drying crops to achieve stable storage is equivalent to 10.4 kg CO₂e/tonne of grain/% moisture loss required (Mortimer et al. 2004). These associated emissions are applied to crops which are more than 0.5% higher in moisture content compared to the standard moisture contents stated in Table 1.

Table 1. Standard moisture contents of crop products in YEN Zero for grain drying purposes.

Crop type	Standard moisture content (%)
Wheat	15
Barley	15
Oats	15
Triticale	15
Rye	15
Oilseed rape	9
Field beans	15

Combining peas	15
Linseed	9
Maize – grain	13
Forage crops	No drying required

Field emissions

When nitrogen fertiliser (either manufactured or organic) is added to the land, some of the nitrogen is lost as nitrous oxide. These emissions also occur from decomposition of crop material that remains on the field. These field emissions are a major contributor to overall emissions from agriculture, potentially contributing over half of the emissions from crop production. There are several pathways in which this nitrous oxide can be produced:

- Direct emissions of nitrous oxide from the soil following fertiliser application
- Indirect emissions of nitrous oxide from ammonia volatilisation following fertiliser application
- Indirect emissions of nitrous oxide from nitrates that are leached following fertiliser application
- Direct emissions of nitrous oxide from decomposing crop material left in the field

There are various means of calculating these emissions. Given that these field emissions are influenced by a range of factors (e.g., weather, soil type, application method) these calculations are approximations based on average data collected from UK field experiments. The approach that YEN Zero is taking is to use the newly built Environmental Benchmarking Calculation Engine (EBCE) that has been developed by ADAS for the AHDB. The EBCE calculates field emissions for a given set of field data (e.g., nitrogen fertiliser application rate, date of application, yearly rainfall). The approach that is taken aligns with that of the UK GHG Inventory (see Brown et al., 2021 and appendices for detailed methodology), which is the way that the UK quantifies GHG emissions from each sector of the economy.

For organic materials, N₂O emissions are calculated based on total N content of the material, and proportion of ammoniacal-N in the material to calculate emissions associated with volatilisation. Figures for the different manure types are sourced from RB209. N₂O emissions from crop residues are calculated using above and belowground crop nitrogen content figures from the UK GHG Inventory. The global warming potential of 298 was used to convert N₂O emissions to CO₂ equivalent emissions, in line with the inventory approach.

Alongside nitrous oxide emissions, the UK GHG Inventory also includes emissions from land use change; in YEN Zero we are assuming that no land use change has occurred, and all fields have not been recently converted from pasture or woodland.

For more detail on how direct and indirect N₂O emissions are calculated in YEN Zero, please refer to the appendices.

Notes

In the pilot year of YEN Zero several decisions have been made to simplify the data collection and analysis process. Firstly, we are not including emissions from capital items (e.g., the manufacture of tractors). Generally, these are only a very minor part of the overall farm GHG emissions. Secondly, the process does not include the allocation of emissions between co-products. Where straw is baled, this yield is not considered, and all emissions are allocated to the grain in the product carbon footprint.



Table 2. Greenhouse gas (GHG) emission factors for crop inputs and operations used to calculate GHG intensities of crop production.

Input	Default Rate Used	Reference	Emission Factor	Reference		
Seed (cereals/OSR/maize)	N/A		0.276/0.73/0.35	kg CO ₂ e/kg	European Commission; JEC E3-database (2008)	
Pesticide manufacture						
Herbicide	0.452	kg ai/ha	Garthwaite (2020)	8.985	kg CO ₂ e/kg	Green (1987)
Insecticide	0.050			25.134		
Fungicide	0.294			6.009		
Growth Regulator	0.481			8.985		
Fertiliser manufacture						
Ammonium nitrate	N/A			3.40	kg CO ₂ e/kg of nutrient	Brenttrup et al. (2018)
Urea				1.91 (+1.6) ^a		
UAN				2.60 (+0.8) ^a		
CAN				3.52		
P ₂ O ₅				0.38		
K ₂ O				0.42		
Lime				0.07	kg CO ₂ e/kg of product	
Operations						
Ploughing	1350	MJ/ha	Williams et al. (2006)	0.08764	kg CO ₂ e/MJ	BEIS (2021)
Power harrow	913					
Drill	280					
Roll	248					
Disc	784					
Shallow min till	784					
Strip tillage	578					
Direct drill	372					
Sprayer	114					
Fertiliser spreader	105					
Lime spreading	336					
Combine harvest – straw chopped	1134					
Combine harvest – w/o straw chopped	1096					
Grain carting	399					
Grain drying	N/A			10.4	kg CO ₂ e/t/%	Mortimer et al. (2004)
Baling	N/A			16	kg CO ₂ e/ha	John Nix (2021)
Fuel				3.33427	kg CO ₂ e/l	BEIS (2021)

^aEmissions from urea hydrolysis included in manufacture emissions

References

- BEIS. 2021. Conversion factors 2021: condensed set (for most users) - revised January 2022. Available at <https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2021> [Accessed 27th January 2022]
- Brentrup, F., Lammel, J., Stephani, T., Christensen, B. 2018. Updated carbon footprint values for mineral fertilizer from different world regions. *11th International Conference on Life Cycle Assessment of Food 2018 (LCA Food)*.
- Brown, P., Cardenas, L., Choudrie, S., Del Vento, S., Karagianni, E., MacCarthy, J., Mullen, P., Passant, N., Richmond, B., Smith, H., Thistlethwaite, G., Thomson, A., Turtle, L., Wakeling, D. 2021. UK Greenhouse Gas Inventory, 1990 to 2019. Annual report for submission under the Framework Convention on Climate Change.
- Chadwick, D., Misslebrook, T., Gilhepsy, S., Williams, J., Bhogal, A., Sagoo, L., Nicholson, F., Webb, J., Anthony, S., Chambers, B. (2005). Ammonia Emissions and Crop N Use Efficiency. Report for WP1b of Defra Project NT2605: 'The Behaviour of Some Different Fertiliser-N Materials – Main Experiments'. London: Defra.
- European Commission. 2008. Biograce, Harmonised calculations of biofuel greenhouse gas emissions in Europe. JEC E3-database.
- Garthwaite, D., Ridley, L., Mace, G., Parrish, G., Barker, I., Rainford, J., MacArthur, R. 2020. Arable Crops in the United Kingdom. *Pesticide Usage Survey Report 284*; pp 1-98.
- Green, M.B. 1987. Energy in pesticide manufacture, distribution, and use. In *Energy in Plant Nutrition and Pest Control*; Helsel, Z.R., ed.; Energy in World Agriculture; Elsevier: Amsterdam, 2; 165-177.
- IPCC, De Klein, C. A. M., Novoa, R. S. A., Ogle, S. M., Smith, K. A., Rochette, P., Wirth, T. C., McConkey, B. G., Mosier, A., & Rypdal, K. 2006. Chapter 11: N₂O Emissions from managed soils, and CO₂ emissions from lime and urea application. In *2006 IPCC Guidelines for National Greenhouse Gas Inventories; Volume 4: Agriculture, Forestry and Other Land Use*. International Panel on Climate Change.
- John Nix (2021) John Nix Pocketbook for Farm Management. 51st edition.
- Misselbrook, T., Cardenas, L., Camp, V., Thorman, R., Williams, J., Rollet, A. and Chambers, B. (2014) An assessment of nitrification inhibitors to reduce nitrous oxide emissions from UK agriculture. *Environment Research Letters*, 9, 11 pp.
- Mortimer, N. D., Elsayed, M. A., Horne, R. E., 2004. *Energy and Greenhouse Gas Emissions for Bioethanol Production from Wheat Grain and Sugar Beet*. Sheffield, UK: Sheffield Hallam University: Final Report no. 23/1.
- Yang, M., Fang, Y., Sun, D. and Shi, Y. (2016) Efficiency of two nitrification inhibitors (dicyandiamide and 3,4-dimethylpyrazole phosphate) on soil nitrogen transformations and plant productivity: a meta-analysis. *Nature Scientific Reports*, 6, 22075, 10 pp.

Appendix

Calculating direct and indirect N₂O emissions from N fertiliser applications

Direct and indirect emissions associated with the application of nitrogen (N) fertilisers were calculated using IPCC 2006 (De Klein et al., 2006) Tier 2 methodology, implementing UK-specific emissions factors and parameters where available. This UK-specific data is sourced from the UK GHG inventory (Brown et al., 2021). Total direct N₂O emissions following N application were calculated using equations derived from Brown et al. (2021), which are specific to the UK environment. The relationship between N applied (N) and N₂O-N emissions is scaled by annual rainfall (R) for AN based fertiliser. Long term rainfall data from the last 10 years for each MORECS square within the UK was used for each YEN Zero entrant, using the entrant's postcode to determine their location. Weather data was sourced from [DTN](#).

For urea and UAN there is no inclusion of rainfall in the calculation of N₂O, due to a lack of experimental evidence. The direct N₂O-N kg/ha emissions from N fertiliser are calculated net of baseline emissions, calculated from Equations 1 and 2 without N fertiliser, and are converted to N₂O from the proportion N in N₂O (44/28).

Equation 1 (Ammonium Nitrate):

$$=1*(1.019709*EXP((0.57 + 0.3962 *(R)/1000 -0.0001942 *N + 0.003248 *(R)/1000 *N) *1) - 1.6297212)$$

Equation 2 (Urea and UAN):

$$=1*(1.01107 * EXP((0.8404 + 0.001518 *N)*1)) - 1.6297212)$$

Indirect N₂O emissions from volatilisation and leaching were calculated using the UK GHG inventory (Brown et al., 2021) and IPCC emission factors (De Klein et al., 2006). The fraction of N applied volatilised to ammonia and subsequently deposited was assumed to be 0.0153 for AN, 0.1103 for urea and 0.055 for UAN (Brown et al., 2021), with emissions of 0.01 kg N₂O/kg N volatilised (De Klein et al., 2006). The fraction of N leached is assumed to be 0.3 and applies to all fertiliser and crop residue N inputs, with emissions from leached N of 0.0075 kg N₂O-N/kg N (De Klein et al., 2006).

For scenarios where a nitrification or urease inhibitor was used the reduction in emissions did not go down to a product level. For nitrification inhibitors a blanket reduction of 43.8% of direct N₂O emissions was used based on previous research, for all N fertiliser forms (Misselbrook et al., 2014; Yang et al., 2016). The influence of urease inhibitors was derived from UK field experiments which measured ammonia emissions from N fertiliser applications with the inhibitor Agrotain (NT26; Chadwick et al., 2005). A percentage reduction in indirect N₂O emissions from volatilisation of 70% was used for urea N forms, and 44% for UAN.

Calculating N₂O emissions from crop residues

Direct N₂O emissions from crop residues were calculated using crop specific figures from the inventory (Brown et al., 2021), which included:

- Dry matter (DM) harvest index (HI) values (the HI value for forage crops was assumed to 1)
- The ratio of below-ground residues to above-ground biomass
- Nitrogen content in above and below ground residues
- The above ground residue retained if residues are removed

Crop yield was used to calculate the amount of residues produced by each crop, the calculation used to determine residue quantities is listed below along with calculations of quantities of N within the residue.

Equation 3, calculating above ground residue DM

$$\begin{aligned} & a) \text{ Dry matter yield; } Y_{dm} \\ & = \text{Yield} * ((100 - \text{crop moisture \%})/100) \end{aligned}$$

$$\begin{aligned} & b) \text{ Above ground residue DM; Residue}_{AG_dm} \\ & = Y_{dm} * ((1-HI)/HI) \end{aligned}$$

Equation 4, calculating below ground residue DM; Residue}_{BG_dm}

$$= (Y_{dm} + \text{Residue}_{AG_dm}) * \text{BG_to_AG_ratio}$$

Equation 5, calculating N content in above and belowground residue

$$= (\text{Residue}_{AG_dm} * \text{AG_N_content_residues}) + (\text{Residue}_{BG_dm} * \text{BG_N_content_residues})$$

Equation 6, calculating residue N if residues are removed from the field

$$= (\text{AG_N} * \text{proportion}_{AG_residue_retained}) + \text{BG_N}$$

For maize, beans and pea crops the IPCC approach is used to calculate N₂O emissions from crop residues. This uses the below calculation to determine above ground residue quantities:

Equation 7, IPCC approach to calculate aboveground residue N content

$$\begin{aligned} & a) \text{ Residue}_{AG_dm} \\ & = (\text{IPCC_Slope} * Y_{dm}) + \text{IPCC_intercept} \end{aligned}$$

$$\begin{aligned} & b) \text{ AG_N} \\ & = \text{Residue}_{AG_dm} * \text{AG_N_content_residues} \end{aligned}$$

Where the slope and intercept values for maize are 1.03 and 0.61 respectively, and the slope and intercept values for beans and peas are 1.13 and 0.85 respectively.

These figures were converted to N₂O using the same method as above after applying an emission factor of 0.01 derived from IPCC Tier 2 methodology (De Klein et al., 2006). The emissions associated with baling the straw (sourced from John Nix, 2021; Table 2) are also considered when residues are removed.

Calculating direct and indirect N₂O emissions from organic materials and manures

Direct N₂O emissions from organic materials and manure are calculated by multiplying the total N in the material applied by an emission factor specific to each organic material, sourced from the inventory (Brown et al., 2021). Total N is calculated by multiplying quantity of material applied (t or m³/ha) by the total N content of the material (kg/m³), sourced from RB209 look up tables.

Indirect N₂O emissions from volatilisation and leaching were calculated using the UK GHG inventory (Brown et al., 2021) and IPCC emission factors (De Klein et al., 2006). The fraction of N leached from organic materials is assumed to be 0.3, with emissions from leached N of 0.0075 kg N₂O-N/kg N (De Klein et al., 2006). The fraction of N applied volatilised to ammonia and subsequently deposited is calculated by adding together the direct NO-N and NH₃-N emissions and multiplying by IPCC EF₄. The equation for this is detailed below.

Equation 8, Indirect N₂O emissions from volatilisation from organic materials

$$= ((\text{Direct N}_2\text{O emissions} * 0.4) + ((\text{rate of manure applied (t or m}^3\text{/ha)} * \text{total ammonium N (kg/m}^3\text{)}) * \text{direct NH}_3 \text{ EF})) * \text{IPCC EF}_4$$

Where total ammonium N in each manure type is sourced from MANNER-NPK, NH₃-N emission factors sourced from the inventory (Brown et al., 2021) and the IPCC EF₄ is 0.014.