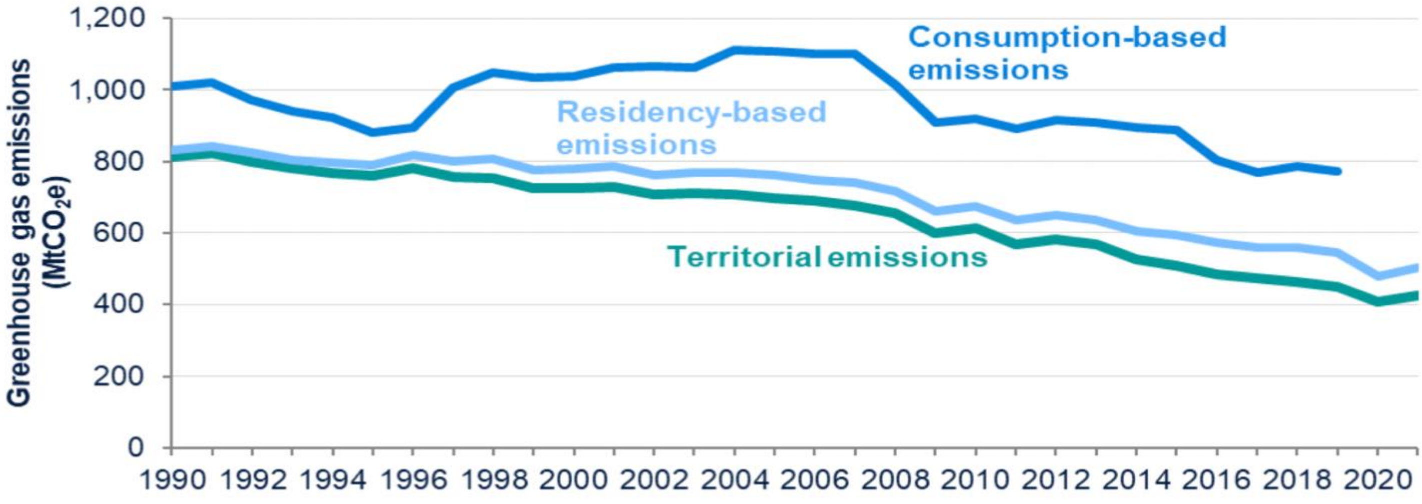
Key Facts – Net-0, Methane, and the Role of Ruminants

Net-0:

- In 2019, the UK government proposed the 'Net-0' target, whereby it committed to bring all greenhouse gas (GHG) emissions to zero by 2050 compared to 1990 levels.[1]
- The Department for Business, Energy, and Industrial Strategy (BEIS) is responsible for publishing estimates of the UK's greenhouse gas (GHG) emissions involved in Net-0, which is used as the baseline for monitoring the Climate Change Act 2008 Net-0 target.
- **Net-0** estimates are also known as **territorial estimates** and are production-based estimates of emissions taken place within the UK's geographical borders.
    - They **include** GHG emissions or removals from:
        - Businesses based in the UK, regardless of where in the world the business is registered.
        - The activities of people that live in the UK, as well as non-UK visitors.
        - Offshore areas where the UK has jurisdiction.
        - Land i.e., forest, crop of grazing land.
    - They **do not include** GHG emissions or removals from:
        - International air travel.
        - International shopping.
        - UK businesses and residents which occur abroad.
        - Burning of biomass (wood, straw, biogases, poultry litter) for energy production.
        - Land i.e., peatland.
        - Production of goods and services that the UK imports from other countries
- **Carbon Footprint** is another measure of GHG emissions into the atmosphere but differs from Net-0 estimates as it takes into account emissions from the UK consumption of goods and services wherever they arise in the supply chain and are known as **consumption emissions**.
    - They **include** GHG emissions from:
        - Goods and services produced and consumed in the UK.
        - Imports.
        - UK households.
    - They **do not include** GHG emissions from UK exports.
- Figure 1[2] illustrates that substituting home-produced goods for imported equivalent, and therefore effectively exporting GHG emissions, makes the UK closer to reaching Net-0, whilst having little impact in the UK carbon footprint.

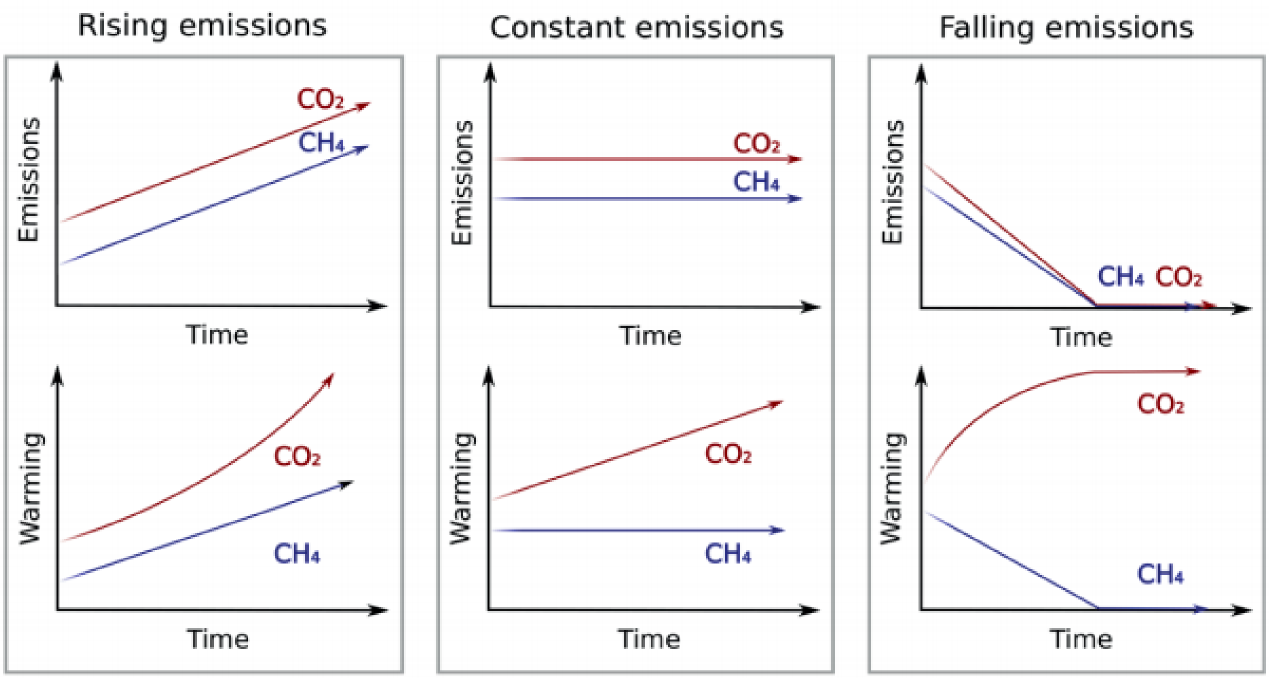
Figure 1: UK territorial, residency-based and consumption-based greenhouse gas emissions, 1990-2021



[1] https://assets.publishing.service.gov.uk/media/6569cb331104cf000dfa7352/net-zero-government-emissions-roadmap.pdf
[2] https://assets.publishing.service.gov.uk/media/65c0d15863a23d0013c821e9/2022-final-greenhouse-gas-emissions-statistical-release.pdf

Distinctions between GHGs

- Often GHG data refers to the emissions of gases to the atmosphere, and not of their total concentration within the atmosphere. This is an important distinction as different GHGs remain in the atmosphere for different periods of time and thus contribute to global warming in different ways. GHGs can broadly be grouped into two categories based on the length of time they remain in the atmosphere:
  - Short-lived climatic pollutants (SLCPs):
    - These are short-lived GHGs which do not accumulate within the atmosphere.
    - Methane (CH_4) is a SLCP with a half-life of approximately 9.6 years[3].
  - Long-lived climatic pollutants (LLCPs):
    - LLCPs are long-lived GHGs which accumulate within the atmosphere.
    - Carbon Dioxide (CO_2) is a LLCP with a half-life in the range of 50-200 years[4].
- There is a notable difference to how global mean temperatures respond to different emission scenarios of SLCPs and LLCPs, exemplified by CO_2 (LLCP) and CH_4 (SLCP) shown in Figure 2[5].
  - Rising emissions:
    - Both CO_2 and CH_4 cause climatic warming.
    - As CO_2 accumulates within the atmosphere any increase in emissions will cause concentrations in the atmosphere to increase (summate), trap more heat and cause an exponential increase in climatic warming.
  - Constant emissions:
    - When emissions of CH_4 is constant, warming of the atmosphere reaches an equilibrium as CH_4 is removed from the atmosphere at the same rate it is being added. Whereas due to the accumulative nature of CO_2 constant emissions are associated with climatic warming.
  - Falling emissions:
    - A reduction in CH_4 emissions will result in climatic cooling **before** emissions are at zero due to its short lifetime within the atmosphere.
    - However, a reduction on CO_2 emissions will still result in warming as long as emissions are above 0. When emissions reach 0, an equilibrium is reached and the temperature response to CO_2 remains constant for many decades due to cumulative CO_2 emissions.



[3] Arora, V. K., Melton, J. R., and Plummer, D.: An assessment of natural methane fluxes simulated by the CLASS-CTEM model, Biogeosciences, 15, 4683–4709, https://doi.org/10.5194/bg-15-4683-2018, 2018.
[4] Inman, M. Carbon is forever. *Nature Clim Change* **1**, 156–158 (2008). https://doi.org/10.1038/climate.2008.122
[5] https://www.oxfordmartin.ox.ac.uk/downloads/academic/Climate_Metrics_%20Under_%20Ambitious%20_Mitigation.pdf

Metrics for Measuring GHG Emissions and Impacts on Climatic Warming

- Metrics are essential for the quantification of how GHG emissions equate to climatic warming. They are important for comparing the effects of different GHGs to support and prioritise policy interventions and mitigation activities.
- Global Warming Potential (GWP):
  - GWP is the heat absorbed by any GHG in the atmosphere, as a multiple of the heat that would be absorbed by the same mass of CO_2. It essentially measures how effective a particular GHG is at trapping heat in the Earth's atmosphere and contributing to climatic warming.
  - GWP is 1 for CO_2.
  - A pollutants GWP depends on the number of years (denoted by the subscript) over which the warming potential is calculated.
- GWP_{100}:
  - The most commonly used metric to quantify GHG emissions.
  - It works by measuring the GWP of a particular GHG over 100 years compared to 1 tonne of CO_2 thereby creating a CO_2 equivalent for each GHG. This enables characterisation and comparison between the warming effects of different GHGs within the atmosphere.
    - By this calculation methane has a GWP_{100} of 25 i.e., 1 tonne of methane in the atmosphere causing warming equivalent to 25 tonnes of CO_2 in the atmosphere over 100 years.
  - Limitations:
    - A gas which is quickly removed from the atmosphere (SLCP) may initially have a large effect on climatic warming, but over longer time periods, at it has been removed, it's warming effects becomes less important. Thus, methane has a GWP_{100} of 25, but a GWP_{25} of 86.
      - This has resulted in:
        - GWP_{100} exaggerates the warming effect of a constant methane source by a factor of 3-4.[6]
        - GWP_{100} underestimates the warming effects of newly emitted methane by a factor of 4-5.
    - GWP_{100} can only be a positive value i.e. signifying global warming, and does not reflect the cooling effect experienced when methane emissions are reduced[7] (Figure 2, 3).
- GWP*
  - Developed by Professors at the University of Oxford as traditional CO_2 equivalent targets across GHGs (LLCPs and SLCPs) are ambiguous and do not consider the unique behaviours of different pollutants within the atmosphere.
  - The metric is intended to complement the traditional GWP_{100} metric to better link emissions of SLCPs with the actual effect of the warming they produce in the atmosphere given their transient nature.
- Comparing GWP_{100} and GWP*
  - Lynch et al 2020 (Figure 3) clearly demonstrate that GWP100 overestimates the warming effects of methane when emissions are constant and when emissions are reduced but underestimates the effects of warming from rising methane emissions.
  - Comparative data:
    - When using the GWP* metric, a 1.5% increase in methane emissions would lead to climate impacts 40% greater than indicated by GWP_{100}.[3]
    - Methane emissions need only fall by 0.35% each year to have a neutral or net-0 impact by 2050.[3]
  - The use of the GWP* metric compared to GWP_{100} illustrates that reducing methane emissions is a short-term solution to the climate crisis. Reducing SLCPs in the atmosphere has a faster measurable impact than reducing LLCPs. However, due to the short lifetime, reducing methane emissions will not contribute to lowering long term global temperature (still determined by CO_2 emissions) required for climate change mitigation.[4]

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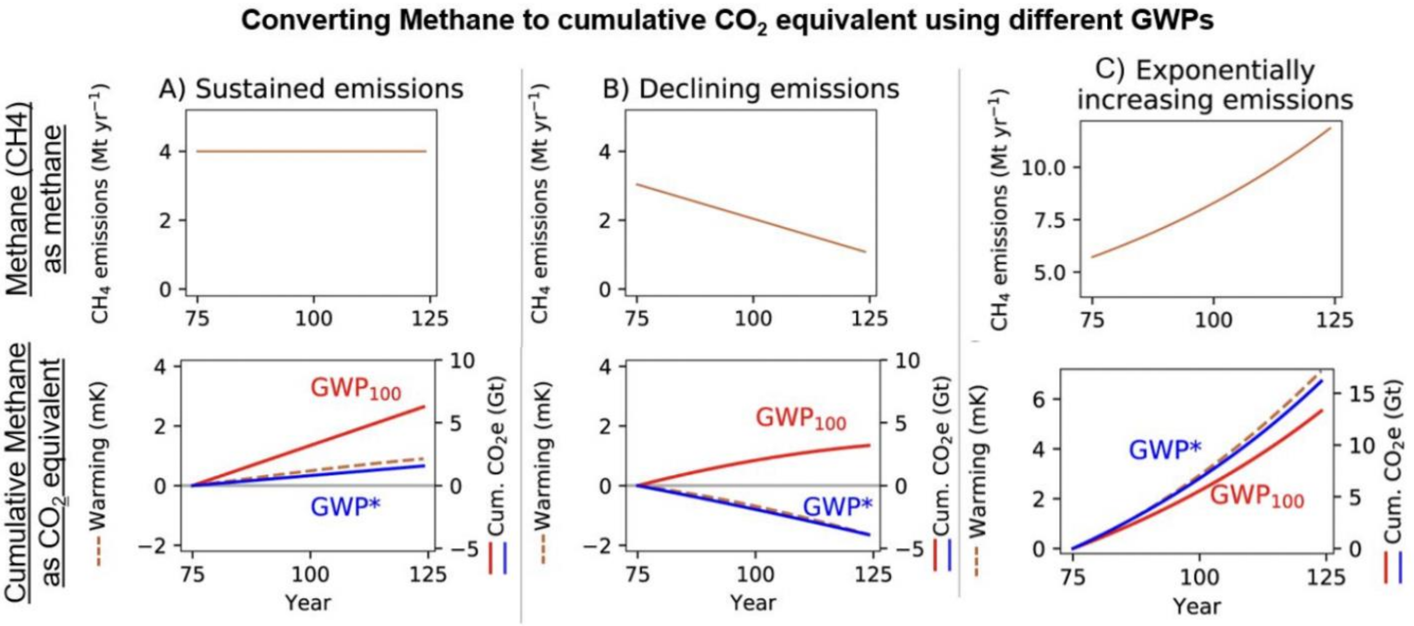
[6] *Costa Jr. C, Wironen M, Racette K, Wollenberg, E. 2021. Global Warming Potential* (GWP*): Understanding the implications for mitigating methane emissions in agriculture. CCAFS Info Note. Wageningen, The Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)*

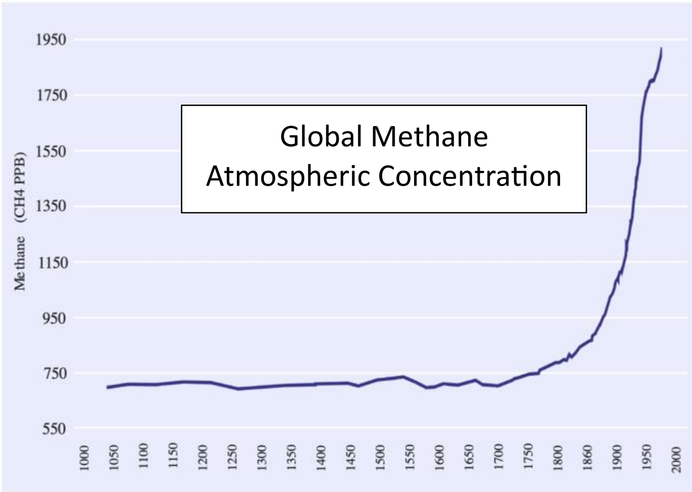
[7] Liu, S., Proudman, J. & Mitloehner, F.M. Rethinking methane from animal agriculture. *CABI Agric Biosci* **2**, 22 (2021). https://doi.org/10.1186/s43170-021-00041-y



Source: John Lynch *et al* 2020 Environ. Res. Lett. 15 044023, Figs 5 & 6

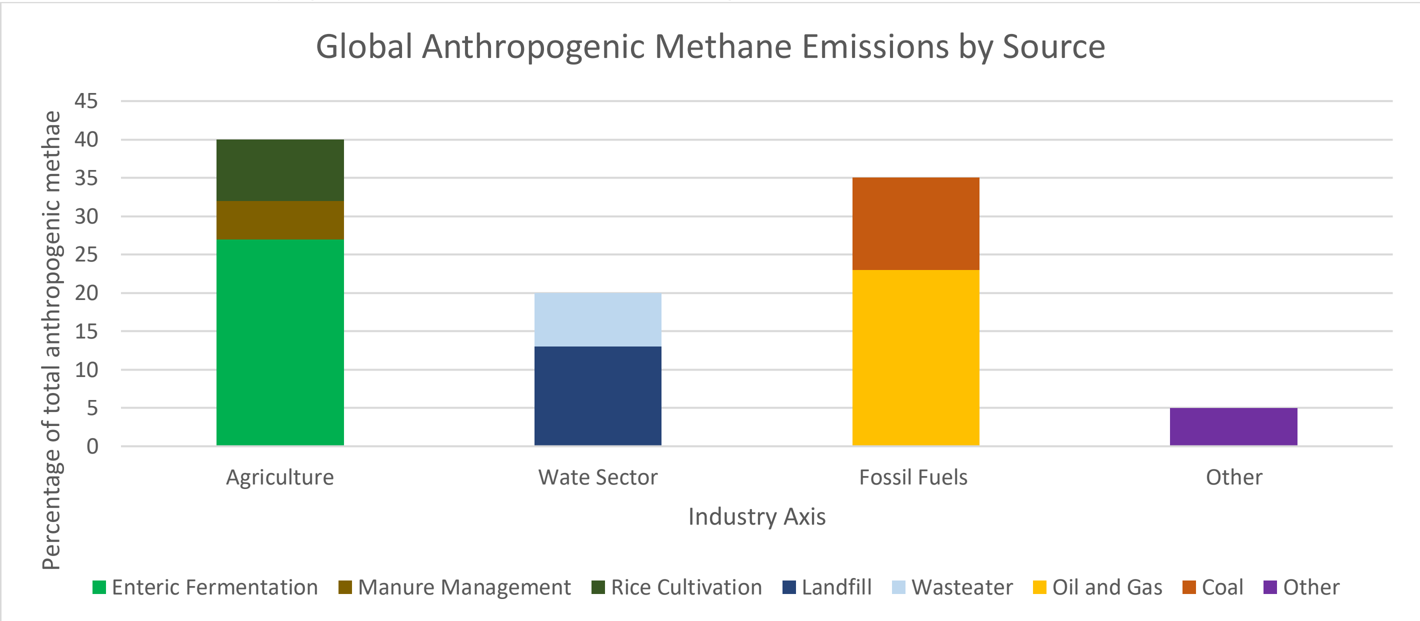
Methane

- Background
  - CH_4 is the second most abundant greenhouse gas in the atmosphere and is the most potent - with 86x the global warming power of CO_2 over the first 20 years since emissions, and 28x more potent over 100 years since emission[8].
  - It is estimated that methane emissions have contributed to approximately 33% of anthropogenic climate change[9].
- Global methane atmospheric concentration
  - Since pre-industrial times, methane's atmospheric concentration has more than doubled (Figure 3).
  - Scientists mainly attribute this to anthropogenic sources, however significant increases in methane emissions can be attributed to natural sources.



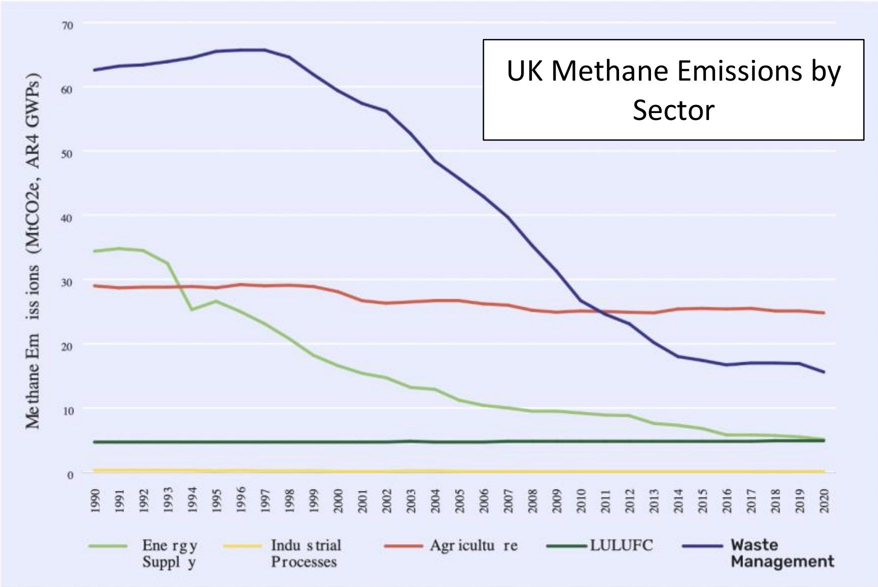
Source: 2 Degrees Institute, 2022.

- Source of emissions:
  - Natural sources – account for approximately 40% of global methane emissions and include:
    - Wetlands - the largest natural contributor of natural methane emissions and contribute 20-30% of atmospheric methane.[10]
      - Wetland emissions are highly variable and are often significant enough to modify the trends.[11]
      - Almost half of the increased emissions from wetlands are due to higher temperatures (0.5 degrees) and more rainfall (2-11% more precipitation)[12]
        - Concern that this is a positive feedback cycle of the effects of climate change further increasing methane emissions.
    - Also include thermokast lakes and melting permafrost.
  - Anthropogenic sources – account for 60% of global methane emissions[13]



[8] Liu, S., Proudman, J. & Mitloehner, F.M. Rethinking methane from animal agriculture. *CABI Agric Biosci* **2**, 22 (2021). https://doi.org/10.1186/s43170-021-00041-y
[9] https://www.globalmethane.org/documents/gmi-mitigation-factsheet.pdf
[10] The Global Methane Budget 2000-2017 (2020)
[11] Skeie, R.B., Hodnebrog, Ø. & Myhre, G. Trends in atmospheric methane concentrations since 1990 were driven and modified by anthropogenic emissions. *Commun Earth Environ* **4**, 317 (2023). https://doi.org/10.1038/s43247-023-00969-1
[12] Peng, S., Lin, X., Thompson, R.L. *et al.* Wetland emission and atmospheric sink changes explain methane growth in 2020. *Nature* **612**, 477–482 (2022). https://doi.org/10.1038/s41586-022-05447-w
[13] UNEP Climate and Clean Air Coalition Estimated Anthropogenic Methane Emissions per Sector

- UK methane emissions
    - In 1990, methane emissions contributed to 17% of the UK's total GHG emissions.
    - Between 1990 and 2020, UK methane emissions reduced by 62%.[6]
    - Methane now accounts for approximately 13% of the UK's net greenhouse gas emissions[14].
    - The largest reductions have occurred in the waste sector (75% reduction), energy sector (84% reduction) and agriculture (15% reduction) – see Figure 5.



Source: BEIS, UK 1990-2020 Greenhouse Gas Inventory.

- Ruminants:
    - UK populations size:
        - Since 1984, UK cattle herd size[15] has reduced by 28.3%, falling in both the beef herds and the dairy herds.[16]
        - Similarly, there has also been a reduction in the sheep herd size of 9.1% over the same 39 years.[12]
    - Therefore, it may be extrapolated that a reducing population of domestic ruminants in the UK, reduces the methane produced from eructation and therefore has created a cooling effect in the atmosphere.
    - Reducing methane emissions from livestock:
        - In 2023, the FSA approved the feed additive Bovaer (3-nitrooxypropanol) for ruminants in the UK. It inhibits the enzyme methyl-coenzyme M reductase which reduces the conversion of hydrogen to methane within the rumen, the final step of methanogenesis.
            - Has been shown to reduce methane emissions from dairy cows by 30-40% when fed regularly, with no discernible effect on feed intake and productivity.[17]
            - A 30% uptake in dairy cow populations would reduce agricultural methane by 5% by 2030, and only cost the average consumer 33p more a year.[18]
        - Gene-editing – methane is a heritable characteristic.
        - Vaccination of methanogenic bacteria – ongoing research at Pirbright.
        - Reduce morbidity and mortality of animals – increased productivity for the time the animal is alive.

[14] https://www.gov.uk/government/publications/united-kingdom-methane-memorandum/united-kingdom-methane-memorandum
[15] UK Annual Timeseries on Agricultural Systems from 1984-2023
[16] https://www.gov.uk/government/statistics/livestock-populations-in-the-united-kingdom/livestock-populations-in-the-united-kingdom-at-1-june-2023
[17] Pitta, D.W., Indugu, N., Melgar, A. *et al.* The effect of 3-nitrooxypropanol, a potent methane inhibitor, on ruminal microbial gene expression profiles in dairy cows. *Microbiome* **10**, 146 (2022). https://doi.org/10.1186/s40168-022-01341-9
[18] https://green-alliance.org.uk/wp-content/uploads/2022/10/Global-methane-pledge.pdf