Enteric Emissions Are Carbon-Neutral

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Lanigan Group’s Analysis of the Sustainability of Canadian Agriculture

This presentation is the first of a 4-part series of analysis on the Sustainability of Canadian Agriculture:

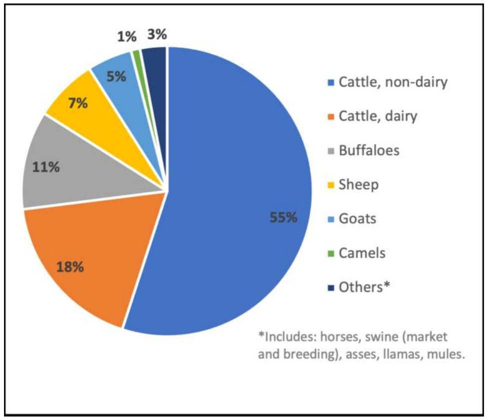
1. ***Misconceptions About the Sustainability of Canadian Agriculture*** addresses false assumptions and misconceptions about Canadian agriculture’s role in global warming due to lack of attention to on-farm sequestration by policymakers.
2. ***Carbon as a Cash Crop*** addresses why Canada’s current narrative for agricultural climate action isn’t working and why carbon credits are ineffective as a basis for incentivizing agricultural climate action. It proposes a more effective alternative based on the concept of incentives for excess sequestration services.
3. ***Enteric Emissions are Climate Neutral*** (this report) presents a detailed analysis of enteric emissions in Canadian dairy which establishes that enteric emissions in Canada are better than non-additive to global warming because they occur in a biogenic carbon cycle that sequesters more carbon than is emitted.
4. ***Carbon Footprint of Canadian Agriculture*** presents a comprehensive estimate of the net carbon footprint for Canadian agriculture that is otherwise unavailable from official sources. It documents why Canadian agriculture is already sustainable because it is already generating over $3 B in unpaid, excess sequestration services.

What are Enteric Emissions?

- Enteric fermentation is a digestive process of ruminant animals (cattle, sheep, goats, buffalo, etc.)
  - Enteric fermentation employs anaerobic microbes to decompose and ferment food in the anima's digestive tract which are more easily absorbed.
  - Ruminant animals contain a dual stomach, the first of which contains most of the microbes, whose primary biological function is enteric fermentation of food
  - This enables ruminant animals to eat more plant-based food that otherwise would not be digestible.
  - Approx 7 – 10% of the ruminant's energy intake is lost as methane (CH4) which is expelled via belches
- Enteric emission of methane accounted for 30% of global methane emissions in 2011 according to the FAO and consequently is closely tracked in IPCC national inventory reports
  - Methane is considered by the IPCC to be 28x worse than CO2 when converted to CO2e
  - This methane slowly decomposes back into CO2 through hydroxyl oxidation, recycling approx. half of its carbon back into carbon dioxide every decade (i.e. atmospheric CH4 has a half-life of approx. 8.6 years) and disappearing within 50 – 60 years
  - CO2 by contrast stays in the atmosphere for a significantly longer period > 100 years
  - While significant over a 25-year horizon, accumulation of methane is not as problematic as CO2 over a longer cycle because the CO2 from decomposing agricultural methane is reabsorbed by crops grown to feed livestock – if total livestock is constant or decreasing
    - Our analysis, presented later, shows that enteric emissions are significantly better than net-zero such that livestock production is best understood as part of a process for carbon capture & storage

Where Do Most Enteric Emissions Come From?

- Cattle are the main contributor to enteric emissions globally.
- Non-ruminant animals (pigs, horses, etc.) also employ enteric fermentation to digest food but to a lesser degree (see figure)
  - Animal age, weight, and dietary composition are the largest factors influencing enteric emissions within a species
- In Canada 96% of enteric emissions originate from cattle (beef and dairy) [NIR 2023]
  - Canada’s National Inventory identifies enteric emissions as Canada’s #2 source of methane emissions after oil & gas extraction



*Includes: horses, swine (market and breeding), asses, llamas, mules.

Global enteric fermentation by source, 2001-2011.
Data from FAO Statistics Division, ESS Working Paper No. 2.

Enteric Fermentation in Context of Canadian Agricultural Emissions

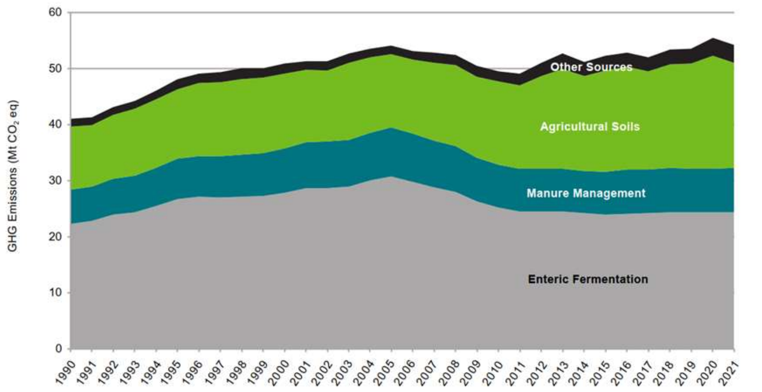
- According Canada’s National Inventory of GHG, livestock-related emissions are 58% of all ag emissions [NIR 2023]

Canada National GHG Inventory Report, 2023

Table 2–9 **GHG Emissions from Agriculture, Selected Years**

GHG Source Category	GHG Emissions (Mt CO_2 eq)								Change (%)	
	1990	2005	2015	2016	2017	2018	2019	2020	1990–2020	2005–2020
Agriculture	**41**	**54**	**52**	**53**	**52**	**53**	**53**	**55**	**34%**	**2%**
Enteric Fermentation	22	31	24	24	24	24	24	24	6%	-23%
Manure Management	6.1	8.7	7.7	7.8	7.9	7.8	7.8	7.8	28%	-11%
Agricultural Soils	11	13	18	18	17	19	19	21	82%	56%
Field Burning of Agricultural Residues	0.22	0.04	0.06	0.05	0.05	0.05	0.05	0.05	-76%	25%
Liming, Urea Application and Other Carbon-Containing Fertilizers	1.2	1.4	2.6	2.5	2.4	2.6	2.7	3.0	155%	114%

Figure 2–18 **Trends in Canadian GHG Emissions from Agriculture Sources (1990–2021)**

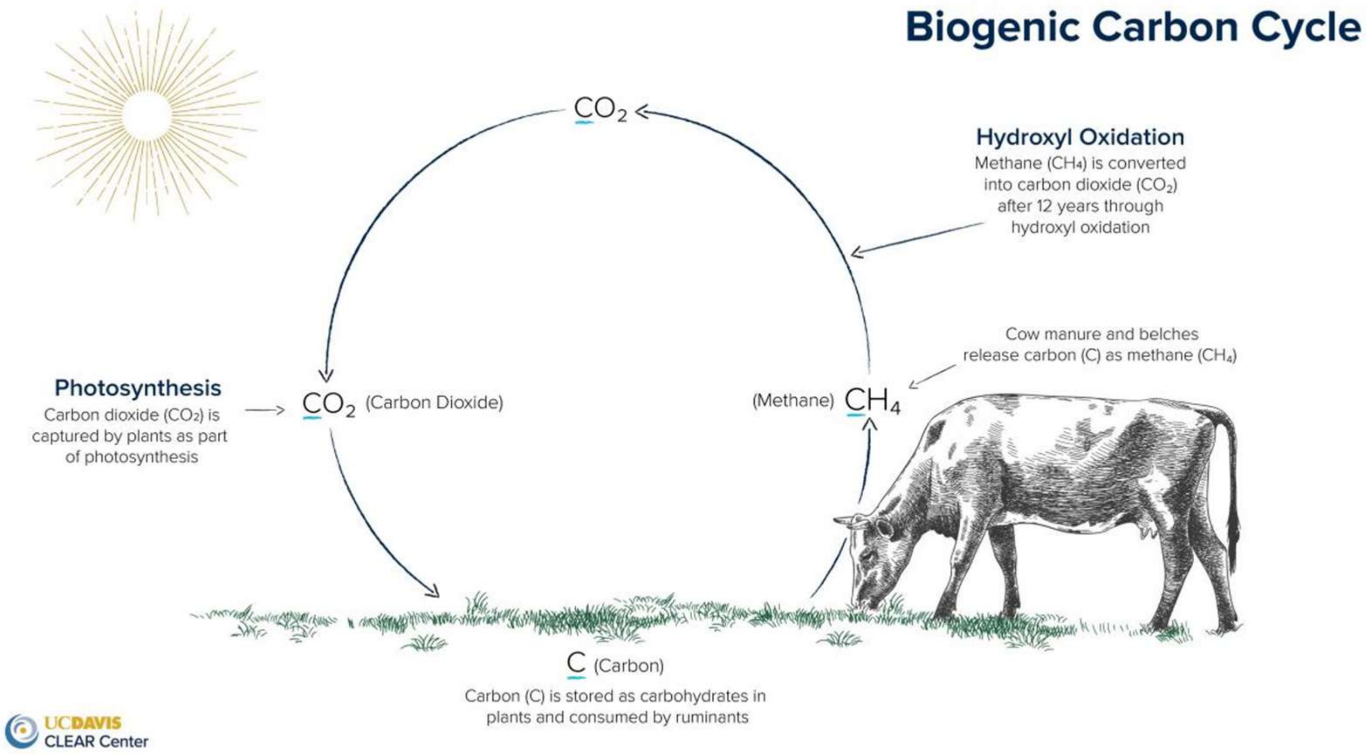


Biogenic Carbon Cycles Have No Carbon Footprint Over Time

- Any opportunity to reduce global emissions contributes to mitigating climate change
- But **not all emissions are additive** to the problem of climate change
  - Biogenic carbon is *not new carbon* in the atmosphere, it is *carbon that is recycling* in a biogenic cycle
  - In a biogenic carbon cycle, plants photosynthesize CO2 from the atmosphere to store carbon in their biomass
  - When the biomass is used to produce emissions (e.g. as a biofuel), those emissions are offset by the sequestration
- The IPCC recognizes the use of bioenergy from biogenic carbon sources as having significant mitigation potential because CO2 is absorbed by growing the plants employed to produce a biofuel [IPCC 2018 AR5 Chapter 11]
  - Sequestration offsets the emissions from the use of bioenergy, hence bioenergy emissions are non-additive
  - A net reduction in global CO2 occurs when a bioenergy fuel is used to displace the use of fossil fuels
- Carbon footprint is the net carbon emission when emissions are offset by carbon removals via sequestration of CO2
  - Net-zero occurs when all emissions are offset by removals (i.e. zero net emissions)
- Any reduction in biogenic emissions represent an *opportunity* for increased carbon capture and storage via natural processes

Enteric Emissions Are Part of a Biogenic Carbon Cycle

- Enteric emissions are **no different** than other biogenic emissions:
  - Enteric fermentation occurs as plant-based food is digested by livestock
  - Carbon is sequestered via photosynthesis in the growing of that food
  - Ruminant animals consume the plants and expel some of the stored carbon as methane via enteric fermentation
  - Methane (CH4) oxidizes into CO2 and H20 as it interacts with atmospheric ozone
  - CO2 from oxidized methane is reabsorbed by plants grown to feed livestock
- Any net reduction in enteric emissions represents increased carbon capture & storage – not simply reduced emissions



Methane (CH_4) is converted into carbon dioxide (CO_2) after 12 years through hydroxyl oxidation

Cow manure and belches release carbon (C) as methane (CH_4)

Carbon dioxide (CO_2) is captured by plants as part of photosynthesis

Carbon (C) is stored as carbohydrates in plants and consumed by ruminants

Isn’t Methane Worse as a GHG Than CO2?

- Enteric emissions are significantly better than methane emissions from the combustion of fossil fuels
  - Carbon emitted from burning fossil fuels is net additional carbon being added to the atmosphere because it is sourced from carbon previously stored underground for millions of years
  - Carbon added to the atmosphere faster than it is absorbed by plants and other natural sinks is the primary cause of climate change

- First Law of Thermodynamics states that energy cannot be created or destroyed
  - Energy out (via methane emissions) cannot exceed energy in (via daily energy intake of food)
  - Even with chemical transformation from CO2 into CH4, it is impossible for enteric emissions to result in higher emission of carbon than the sequestration of carbon in the plants eaten

- We will demonstrate that this remains true for enteric emissions even when we account for:
  - CH4 having a 25x worse impact than CO2 as a GHG affecting climate change (not entirely true for biogenic methane)
  - The molecular balance of carbon within all livestock-related emissions (e.g. manure-related methane)
  - Livestock respiration of CO2 which is not usually included as an agricultural emission
  - Soil-related emissions from the decomposition of residues from crops harvested for livestock consumption
  - Manure decomposition causing N2O emissions that are ~300x worse impact than CO2

Example: The Emissions of a Single Dairy Cow – 1 of 2

Consider a simplified case of a single 600 kg milking cow (the average weight of a dairy cow in Canada is 634 kg):

1. Requires 9,490 kg of Dry Matter Intake (DMI) per year to maintain body mass and produce milk
   [Nutrient Requirements of Dairy Cattle, 7th Edition, National Academic Press, 2001]
   a) Which in turn requires 11,805 kg of preharvest feed consisting of 5,548 kg C and producing 6,131 kg of crop residue (see annex for details)
   b) 20,329 kg of CO2 is photosynthesized by crops to accumulate this amount of carbon
   c) In this analysis we are assuming that the cow eats to maintain its body weight so no additional carbon storage is attributed to growing its live biomass
2. Crop residue after harvest produces 738 kg C and 4 kg N loss via decomposition and respiration (based on annualized rates), i.e. 3,827 kg CO2e
3. The cow produces 5.58 kg volatile solids (VS) in manure / day [IPCC factor], i.e. 2,037 kg manure VS /year
   a) Which volatizes to 0.02 kg CH4/kg VS [IPCC Factor] in drylot storage, or 41 kg CH4 or 1,018 kg CO2e /year
4. Produces 141 kg CH4 per year via enteric fermentation [Ominski 2007], equating to 3,525 kg CO2e
5. The cow breathing will exhale 6.137 kg CO2/day via respiration [Kinsman 1995], or 2,240 kg CO2 / yr
6. Assuming that the manure is also used as fertilizer, another 0.001 kg CH4 per kg VS will also be emitted when spread (2 kg CH4, or 7.5 kg CO2e)
   a) The manure contains 0.25 kg N per Kg VS [OMAFRA], for a total of 500 kg N which volatilizes as 4.5 kg N20 or 835 Kg CO2e
7. Total direct emissions from a single cow are 3,827 + 1,018 + 3,525 + 2,240 + 7.5 + 835 = 11,453 kg CO3e

Example: The Emissions of a Single Dairy Cow – 2 of 2

8. The lactating cow will produce 30 L of milk per day over 10 months, or 9,125 L per year consisting of approx. 101 g C per L of milk, i.e. 922 kg C/yr
    a) We assume that all this carbon is emitted after human consumption (not proven)
    b) Indirect emissions from milk produced (excluding transportation and agrichemical use) are 3,377 kg CO2e

Net carbon footprint is 20,329 – 11,453 – 3,377 kg CO2e = 5,499 kg of CO2 sequestered per dairy cow per year (i.e. 55% more than enteric emissions)

a) Since the cow is maintaining its body mass in this analysis, the net sequestration of 5.5 Mg of CO2 per cow is contributed to soil carbon via crop residue, urine, and manure
b) Note that this calculation did not presume that enteric emissions are biogenic. In a Canadian context, the impact of volatized methane in steps 3(a) and (4) is zero because it is biogenic, yielding net sequestration of 10 Mg per adult cow per year

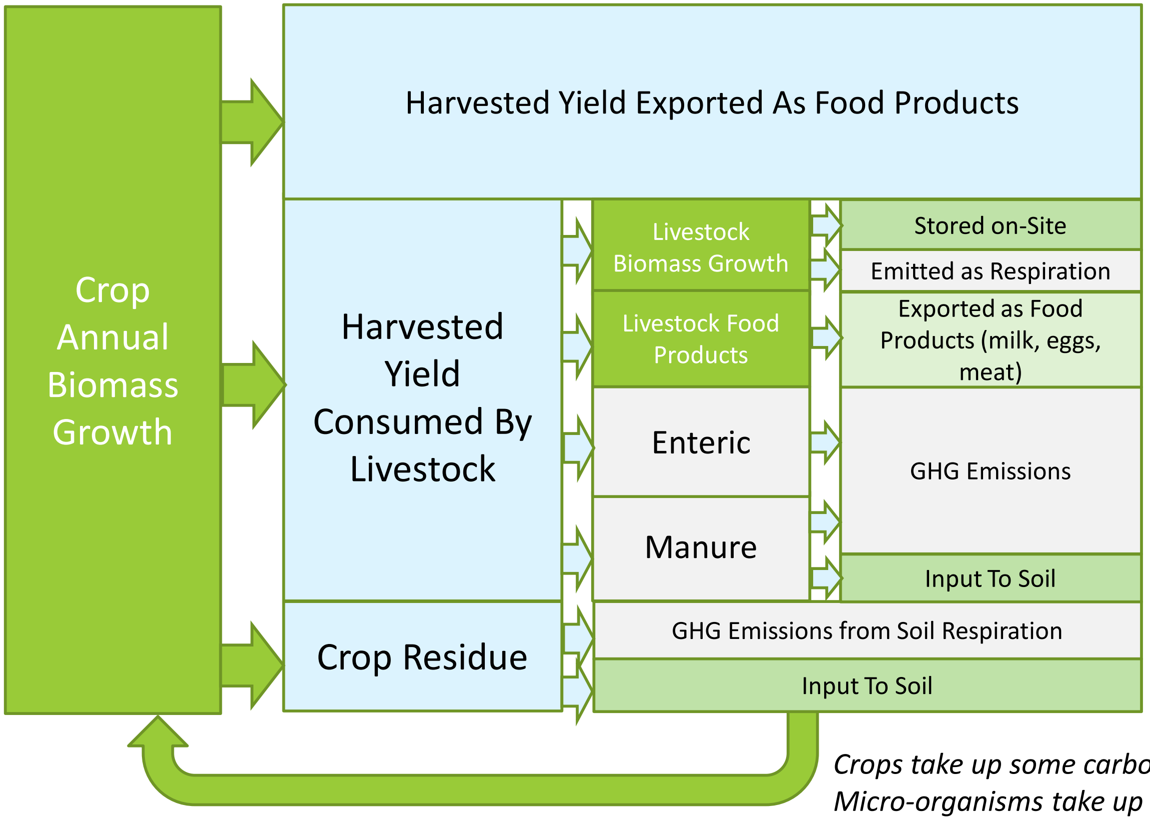
Case Study: Dairy Farm-Level Enteric Emissions

- While the simplified case of a single dairy cow illustrates that livestock emissions are more than offset by carbon sequestration, it is a highly simplified example compared to a real farm.
  - Nonetheless it establishes that the worst case still results in sequestration of 5 Tonnes of carbon per year per lactating head of cattle, or 10 Tonnes on the basis of a biogenic carbon cycle that assigns zero weight to volatized methane in regions where total agricultural methane emissions are flat or falling (e.g. Canada, USA)

- So, we modeled the entire carbon footprint of an operational dairy farm in Eastern Ontario:
  - 190 head of cattle
  - Growing 1500 T of crops annually to feed them (hay, soybean, corn, barley)
  - Generating 5,000 T Manure per year

- In this case study (as illustrated on the next slide):
  - A portion of the crops grown is sold for human consumption, so we don't count it as sequestered carbon in the herd's biogenic cycle
  - Of the amount of fed consumed by livestock, we account for the proportion used to:
    - Sustain the cattle via respiration of CO2
    - Maintain the body weight of the herd
    - Produce milk which is exported for human consumption
    - Generate enteric emissions
    - Excrete manure
  - We also account for the decomposition of crop residue post harvest and attribute emissions from that decomposition in the same year as the harvest
  - In this analysis, we assign a GWP100 cost of 25 to methane when converting it to a CO2 equivalent to demonstrate that enteric emissions are still climate neutral under traditional analysis assumptions

Dairy Farm Case Study of Crops Grown to Sustain Livestock



No annual sequestration when number of livestock stays the same year over year, stored carbon is ultimately released when animals are slaughtered

Embedded Carbon in Harvested Farm Products Is assumed to be released when consumed by humans

Emissions primarily of N2O & CH4

Sequestration net of emissions above

Emissions primarily of N2O & CO2 from both residue & fertilizer

Sequestration net of N2O & CO2 emitted above

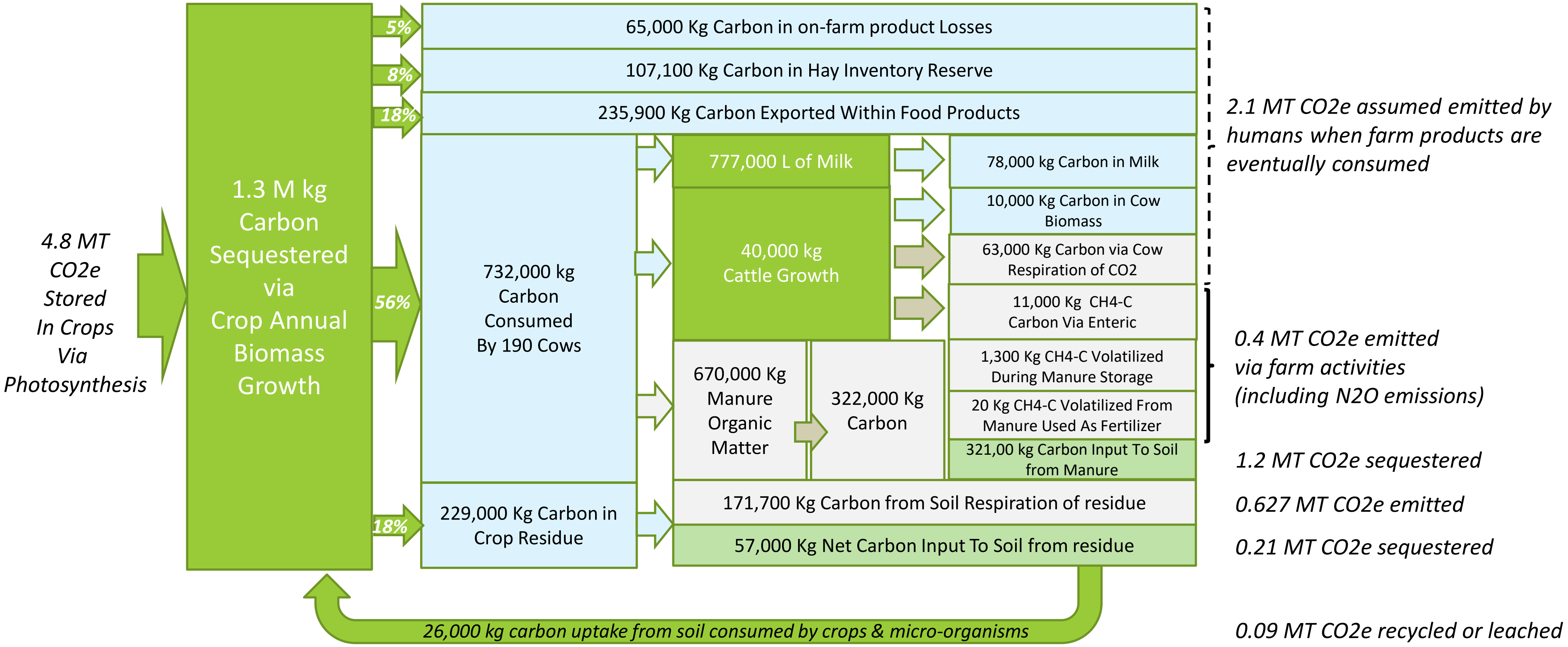
Crops take up some carbon via their roots in addition to via photosynthesis, Micro-organisms take up carbon to grow, some carbon is leached from soil

Case Study: Dairy Farm Carbon Accounting

- Our model traces the outcome of each mole of carbon on a mass balance basis from atmospheric CO2 source into plants, crops & residue, harvested crops exported as food, harvested crops consumed on-site by cattle, cattle biomass, cattle respiration of CO2, milk products, enteric and manure related emissions, and carbon input to soil
  - We were able to trace the carbon pathway to within 10% of total carbon sequestered by crops (i.e. within modelling error)
  - We accounted for molecular weight ratios from CO2 to plant carbon to CH4 and to carbon glucose / carbohydrate / sugars
  - We also included the associated emissions of N2O in manure
  - We assumed an average degree of waste in crop yield and lost milk production
  - The next slide illustrates the different carbon pathways modelled

- We also separately modelled all emissions (Scopes 1, 2, and 3) as well as other sequestration (e.g. from farm trees)
  - Even if we were to include all enteric and manure emissions, and exclude sequestration within the harvested yield, the dairy farm was still better than carbon neutral due to the sequestration of carbon by perennial plants (farm trees)
  - See Annex for details

Where Does the Carbon Sequestered in Crops Grown Go?
Case study of Ontario Dairy farm



4.8 MT CO2e Stored In Crops Via Photosynthesis

1.3 M kg Carbon Sequestered via Crop Annual Biomass Growth

5% 65,000 Kg Carbon in on-farm product Losses

8% 107,100 Kg Carbon in Hay Inventory Reserve

18% 235,900 Kg Carbon Exported Within Food Products

56% 732,000 kg Carbon Consumed By 190 Cows

777,000 L of Milk

40,000 kg Cattle Growth

78,000 kg Carbon in Milk

10,000 Kg Carbon in Cow Biomass

63,000 Kg Carbon via Cow Respiration of CO2

2.1 MT CO2e assumed emitted by humans when farm products are eventually consumed

11,000 Kg CH4-C Carbon Via Enteric

670,000 Kg Manure Organic Matter

322,000 Kg Carbon

1,300 Kg CH4-C Volatilized During Manure Storage

20 Kg CH4-C Volatilized From Manure Used As Fertilizer

0.4 MT CO2e emitted via farm activities (including N2O emissions)

321,00 kg Carbon Input To Soil from Manure

1.2 MT CO2e sequestered

18% 229,000 Kg Carbon in Crop Residue

171,700 Kg Carbon from Soil Respiration of residue

0.627 MT CO2e emitted

57,000 Kg Net Carbon Input To Soil from residue

0.21 MT CO2e sequestered

26,000 kg carbon uptake from soil consumed by crops & micro-organisms

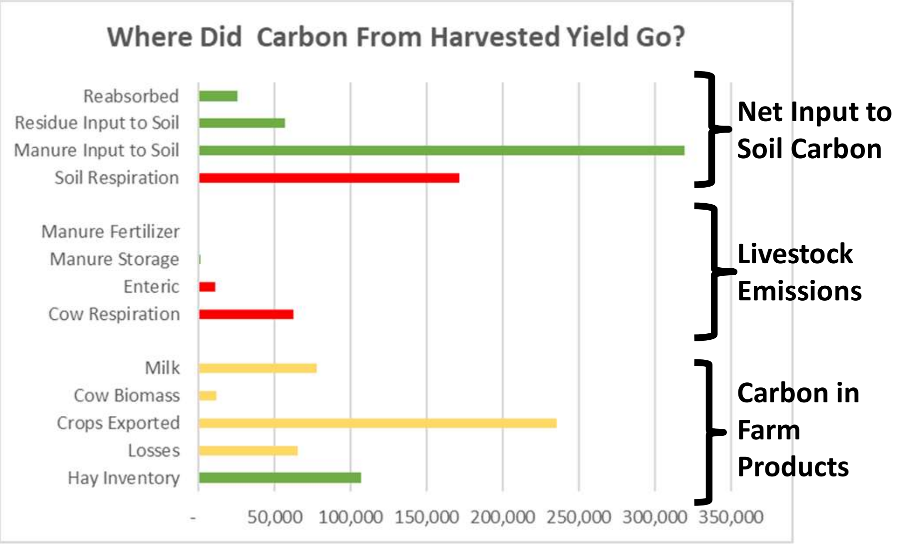
0.09 MT CO2e recycled or leached

Livestock-Related Emissions in Context of Harvested Yield

- This chart of the same data from the previous slide better illustrates the relative magnitude of where the carbon sequestered in the growing of crops ends up

- Impact of manure and enteric emissions is minor when all food for cattle is grown on-site (impact of feed supplementation is minimal)
  - Even if the dairy farm imported all food except for hay eaten by its cattle, and did not pasture its dry cows, all livestock emissions are entirely offset by sequestration of carbon in the hay grown
  - The results of this case study reveals that the farm only needs to grow 20% of the hay eaten by cattle and no other feed to break even on enteric and manure-related emissions
  - At a provincial or national scale, the exchange of livestock feed between farms enables the transfer of emissions removals (aka “insets”) between farms, hence enteric and manure-related emissions are NEVER additive causes to climate change

- In other words, enteric and manure-related emissions **are no more additive than emissions from bio-fuels** because the carbon released is offset by the carbon sequestered in the process that creates the emission
  - In fact, livestock emissions are arguably better if we account for zero impact from methane in regions where overall agricultural methane emissions are flat or falling year over year



Summary of Net Sequestration in Dairy Farm Case Study

- If we eliminate the carbon transferred or stored in human food, the table at the right illustrates that livestock related emissions (enteric and manure-related) are small in comparison to emissions from soil respiration that occurs in the decomposition of crop residues
- Overall, the biogenic carbon cycle is significantly carbon negative on an annual basis, sequestering more carbon than is emitted annually from livestock-related emissions
- This sequestration was produced by 190 cattle of various ages, resulting in a net sequestration of approx. 10 metric tonnes of CO2e per head
    - Higher than the single cow model because not every cow is lactating and generating the same high level of emissions, yet is still consuming food that sequesters carbon
    - We round down to allow for 10% modelling error

Sequesterd in Growing Crops		1,304,105	kg C
Less Eliminations			
	Hay Inventory	- 107,113	
	Losses	- 65,205	
	Crops Exported	- 235,846	
	Cow Biomass	- 12,207	
	Milk	- 78,164	
	Cow Respiration	- 62,868	
Net Carbon Sequestered via Crops		742,702	kg C
Emissions			
	Enteric	- 11,246	
	Manure Storage	- 1,354	
	Manure Fertilizer	- 20	
	Soil Respiration	- 171,746	
Balance	Net Sequestered	558,337	kg C
		2,045,778	kg CO2e/herd
		10,767	kg CO2e/head
		10.8	Mg CO2e/head
		10.8	T CO2e/head

$680 M of Unpaid Excess Sequestration Services By Canadian Dairy

- According to Agriculture Canada, in 2022 there were 1.3919 M head of adult & heifer dairy cows in Canada
- Depending on herd composition (ratio of lactating to more juvenile heifers & calves) our research shows that we can reasonably expect net sequestration of 5 – 10 Tonnes CO2e per head per year
- Using the midpoint of this range (7.5 T CO2e/head),
  - the dairy sector in Canada is sequestering, on an unpaid basis, 10.4 MT of CO2e per year
- If fairly-valued based on the social cost of carbon established via the Federal Carbon Tax ($65 /T CO2e),
  - the social value of the unpaid excess sequestration services provided by the Canadian dairy sector is over $678 M / year
  - If we further assign a zero weight to agricultural methane, then the excess sequestration is in Canadian dairy is over 10 Tonne per head, producing a social value of over $930 M / year
- Fairly compensating the 3,739 dairy farms in Canada for excess sequestration would increase farm incomes by $180K per farm
  - $250 K / farm in the case of zero climate impact from agricultural methane
  - More than sufficient to fund further improvements in farm sequestration services
  - This could be accomplished without budgetary impact by redirecting the proceeds from the federal carbon tax to farmers – instead of refunding the money back to the consumers of fossil fuels

Summary of Findings

- Reducing enteric emissions is important because any emission reduction is beneficial in mitigating climate change
    - As the second largest source of methane emissions in Canada, reducing enteric emissions presents a significant opportunity

- However, ***enteric emissions are no different than any other bioenergy emission*** and **are *non-additive to the problem of climate change*** even if they are not mitigated
    - We demonstrated this via a simplified calculation for a single dairy cow that shows that the enteric emissions are sequestered in the same year that they occur
        - In fact, the cow can be seen as a mechanism for carbon capture and storage that sequesters a minimum of 5 Tonnes of CO2/year
    - We provided a detailed case study that shows the disposition of carbon via crops consumed by livestock from an average sized, operating dairy farm in Eastern Ontario
        - Soil respiration emissions from decomposition of crop residue are greater than enteric emissions from livestock
        - Manure-related emissions are negligible compared to other emissions
        - More carbon is input to soil than is emitted from livestock-related emissions
        - Exported farm products consumed ultimately by humans & livestock off-farm are a larger disposition of carbon than enteric emissions
        - The herd sequestered carbon at the rate of 10 Tonnes CO2 / head per year

- The Canadian dairy sector is sequestering 10.4 MT CO2e per year on an unpaid basis of $678 M

- Canada needs to prioritize non-agricultural methane emissions if it is to make meaningful progress in mitigating climate change while doing more to support further improvement in Canadian dairy emissions

Key Takeaways

1. Our analysis shows that, contrary to popular myth, livestock emissions do NOT contribute to climate change because every gram of carbon in those emissions has been offset by the carbon sequestered in the plants eaten by those animals.
   - ✓ in fact, livestock-based products are better than net-zero because of the biogenic recycling of carbon each year.
   - ✓ For example, the minimum sequestration per lactating dairy cow is 5 MT CO2e/year, or 10 Mg if we recognize agricultural methane as biogenic

2. Even on a cumulative basis, considering that methane has higher impact as a GHG than CO2 on short-term global warming, enteric emissions do not contribute to long-term climate impact because they break down into CO2 over a decade and this CO2 is reabsorbed via photosynthesis into the plants grown to feed livestock (and by other perennials such as pasture and trees).

3. In practice, we should view livestock production as an economically positive mechanism for carbon capture and storage. Incenting dairy farmers to do better by incenting them for their excess sequestration could raise farm incomes by an average of $70 K per year

4. The current national inventory of GHG report shows that livestock related emissions are over half of all agriculture-related emissions, so this implies that Canadian ag is more sustainable than widely believed. The actual carbon footprint of Canadian agriculture is the subject of a sperate analysis.

5. Although Canadian enteric and manure-related emissions may appear large, they do not impact global warming and should not be prioritized over higher-impact climate mitigation initiatives such as:
   - ❖ Reducing the use of fossil fuels and synthetic fertilizer that do contribute to non-biogenic GHG in the atmosphere
   - ❖ Significantly increasing on-farm sequestration of CO2 via proven agroforestry methods instead of subsidizing unproven carbon capture methods during fossil fuel extraction and processing

Annex

Related Research & Bibliography – 1 of 2

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

- Concurs that enteric emissions are biogenic and non-additive. Further observes that enteric emissions have fallen in the USA over the past 5 years due to improvements in livestock productivity.

[Allen MR. 2021] Short-lived promise? The science and policy of cumulative and short-lived climate pollutants. Oxford Martin Policy Paper; 2015. http://www.oxfordmartin.ox.ac.uk/downloads/briefings/Short_Lived_Promise.pdf.

- Argues that it is better to prioritize early reductions in peak CO2 & N2O over short lived climate pollutants (SLCP) such as CH4, black carbon aerosols & HFCs because early SLCP mitigation will have very little impact on eventual peak warming due primarily to CO2

[Badr, O., Probert, S.D., O'Callaghan, P.W., 1992] Sinks for atmospheric methane, Applied Energy, Vol 41, Issue 2, 1992, pp 137-147 https://doi.org/10.1016/0306-2619(92)90041-9

- Identifies several natural sinks in the methane to CO2 cycle

[EPA, 1995] Greenhouse gas biogenic sources. In: Fifth edition compilation of air pollutant emissions factors, vol. 1. Raleigh: EPA; 1995. https://www3.epa.gov/ttn/chief/ap42/ch14/index.html.

- Classifies enteric emissions as biogenic carbon

[Alexander, 2015] Drivers for Global Agriculture Land Use Change: nexus of diet, population, yield & bioenergy, published in Global Environmental Change, https://doi.org/10.1016/j.gloenvcha.2015.08.011

University California at Davis has published several "explainers" and videos on the biogenic nature of carbon emissions. They highlight why we should see cattle production as a means of carbon capture – instead of as an emissions problem that contributes to climate change

[Ominski, 2007] Ominski, K.H. et al, Estimates of enteric methane emissions from cattle in Canada using the IPCC Tier-2 methodology, Canadian Journal of Animal Science, 2007

Related Research & Bibliography – 2 of 2

[Kinsman, 1995] Kinsman, R. et al, Methane and Carbon Dioxide Emissions from Dairy Cows in Full Lactation Monitored over a 6-month Period, Centre for Food & Animal Research, Agriculture & Agri-food Canada, 1995

[Cain, 2019] Cain, M., et. al, I*mproved calculation of warming-equivalent emissions for short-lived climate pollutants*, Climate & Atmospheric Science, Sept, 2019, doi:10.1038/s41612-019-0086-4

[NIR 2022] Canada National Inventory Report on Greenhouse Gas Emissions, Environment Canada, 2022

FAO Statistics Division, ESS Working Paper No. 2

Nutrient Requirements of Dairy Cattle, 7th Edition, National Academic Press, 2001

IPCC Assessment Report 5, Chapter 11, Agriculture, Forestry, and Other Land Use

IPCC Good Practice Guidance and Uncertainty Management in National GHG Inventories – CH4 & N20 Emissions from livestock manure

[OMAFRA] Ontario Fact Sheet: Available Nutrients and Value for Manure From Various Livestock Types, Order No. 13-043, AGDEX 538, August 2013, Ontario Ministry of Agriculture and Food &Ministry of Rural Affairs

What is the difference between a herd of cows and a closed power plant?

Suppose all carbon in the form of GHGs were taxed:

- A power station emits CO2 by burning fossil fuels.
  - This CO2 is taxed while the plant operates.
  - When it shuts down permanently, it emits no more CO2, so is no longer taxed.
  - However, the CO2 already emitted continues to affect the climate for hundreds, or potentially, thousands of years.
  - So, even after closing down, that power station still contributes to holding up global temperatures because of the CO2 that remains in the atmosphere.
- A herd of cows emits methane, so a farmer might be taxed for those emissions if we were to ignore the biogenic cycle.
  - If the herd remains the same size with the same methane emissions every year, it will maintain the same amount of additional methane in the atmosphere year on year (because annual additions are replaced by decomposition of methane into CO2 absorbed by plants).
  - In terms of contribution to global warming, this is equivalent to the closed power station.
- The power station pushed up global temperatures when it was running in the past, but neither a herd of cattle of constant size, nor a defunct power station is pushing up global temperatures in this scenario.
- However, under almost all proposed systems for taxing emissions that attempt to include methane, the farmer would get taxed for their herd's methane emissions every year the cows were alive, even though the owner of the closed power station would not.
- Conclusion: We cannot fairly apply carbon taxes to agricultural livestock emissions

Adapted from: [Cain M. 2018]: A new way to assess 'global warming potential' of short-lived pollutants. Carbon Brief Ltd; 2018.
https://www.carbonbrief.org/guest-post-a-new-way-to-assess-global-warming-potential-of-short-lived-pollutants

Single Dairy Cow Feed Emission Calculations

The dairy cow is assumed to use the feed mix shown below (taken from the case study of a real dairy farm).

- Approx 4% of the cow's daily intake is feed supplements that are not grown onsite.

The single cow analysis does not factor in the indirect emissions from agrichemical fertilizer and feed production, nor the transportation of those manufactured products to the farm. It also excludes the emissions from applying fertilizer to grow the cow's feed and farm fuel consumed in harvesting crops.

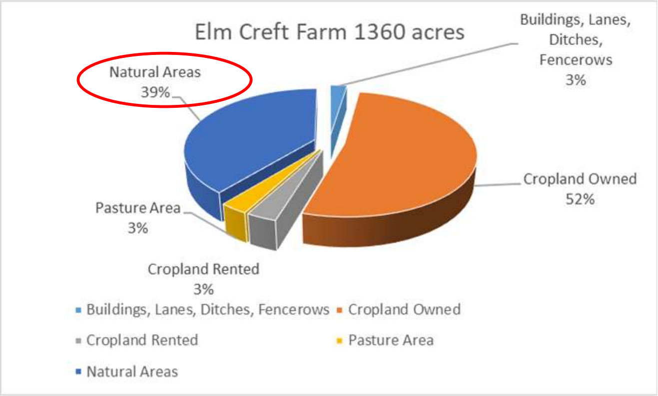
- The dairy farm carbon modelling case study does factor in all those emission sources which contribute 7% to total farm emissions
- Hence the error from excluded factors in emission calculations for the single cow model is less than 10%

Feed MIx		Crop Consumption (HY Kg)	MJ	PreHarvest Biomass Kg	%Carbon	Carbon (kg)	CO2e kg Sequestered	AG Residue to HY	BG Residue to HY	N Content to AG Residue	N Content to BG Residue	AG Crop Residue Kg	BG Crop Residue kg	Total Residue	%Carbon	kg C in Residue	Kg N in Residue	Avg Carbon Lost / Yr	Kg C Soil Respiration	Avg N Lost/Yr	Kg N Soil Respiration	kg CO2e
63%	Soybean	5,994	110,594	7,972	47%	3,747	13,729	0.15	0.17	0.006	0.01	899	1,019	1,918	0.47	902	15.6	0.589	531	0.166	2.59	2,717
2%	Corn-Grain	220	4,061	271	47%	127	466	0.14	0.09	0.005	0.007	31	20	51	0.47	24	0.3	0.589	14	0.166	0.05	66
11%	Corn-Silage	1,013	18,683	1,033	47%	485	1,779	0.001	0.022	0.013	0.007	1	22	23	0.47	11	0.2	0.589	6	0.166	0.03	32
15%	Barley	1,418	26,156	1,956	47%	919	3,369	0.24	0.14	0.00764	0.01	340	198	539	0.47	253	4.6	0.589	149	0.166	0.76	773
5%	Hay	440	8,123	572	47%	269	986	0.01	0.3	0.015	0.015	4	132	136	0.47	64	2.0	0.589	38	0.166	0.34	240
4%	Supplements	-	-	-	47%	-	-	-	-	-	-	-	-	-	0.47	-	-	0.589	-	0.166	-	-
		9,085	167,617	11,805		5,548	20,329					1,276	1,392	2,667		1,254	23		738		4	3,827

Enteric Emissions		
IPCC Tier 1 Factor	128	kg CH4 / head
IPCC Tier 2 Methane CF	0.065	
IPCC Tier 2 Methane EF	196	kg CH4 / head
PCC 2007 CH4 Conversion Factor	25	
CO2e	4,894	Kg CO2e
Canada Tier 3 [Ominski 2007]	141	kg CH4 / head
	3,525	Kg CO2e

	Manure Emissions				
	IPCC Tier 2 Factor Manure Produced	5.58	kg VS / day		
		2,037	kg VS / Yr		
	Digestibility of Feed	75%	IPCC 2006 Tier 2 Factor		
	Methane Producing Capacity	0.01	Drylot		
	Methane EM Drylot Storage	0.02	kg CH4/ kg VS	Drylot is the most common storage method in Canada	
		41	Kg CH4 / yr	1018.35	Kg CO2e
	CH4 Emissions Per IPCC Eq 10.23	0.273	Kg CH4		
		1.000	kg CO2e		

Elm Creft Farm, Perth Ont



Farm Activity

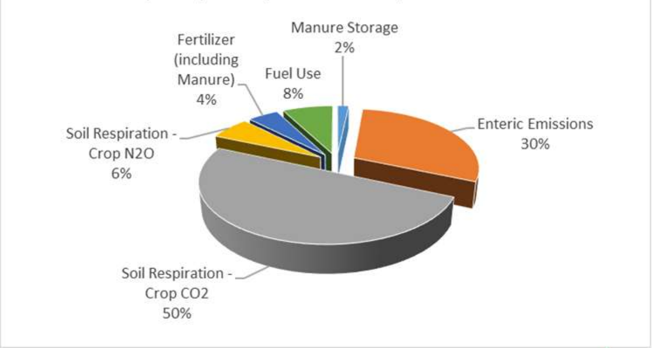
Carbon Negative Dairy Farm

Livestock

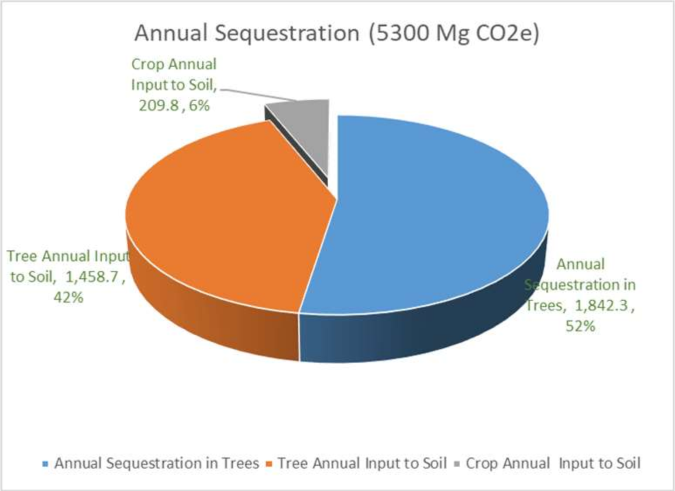
- 190 Dairy Cattle
- 776,728 L Milk Produced
- 5,050 T Manure Nutrients

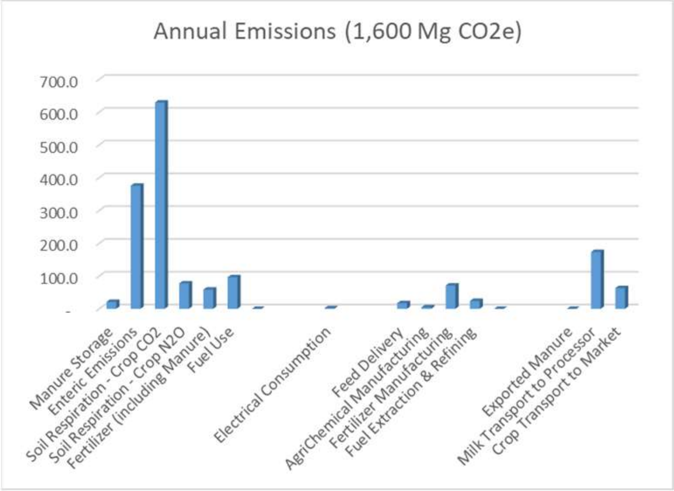
Crop Yields

- 1,753 T Hay
- 714 T Corn – Grain
- 322 T Corn - Silage
- 100 T Barley
- 172 T Soybeans



Carbon Footprint is Significantly Carbon-Negative





Scope 1
85%

Scope 2
0.2%

Scope 3
14%