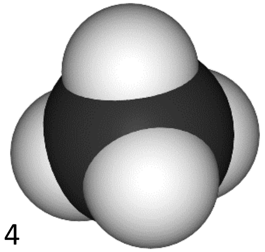
Methane, Feed Intake, and Maintenance Energy

Megan Rolf, Kansas State University

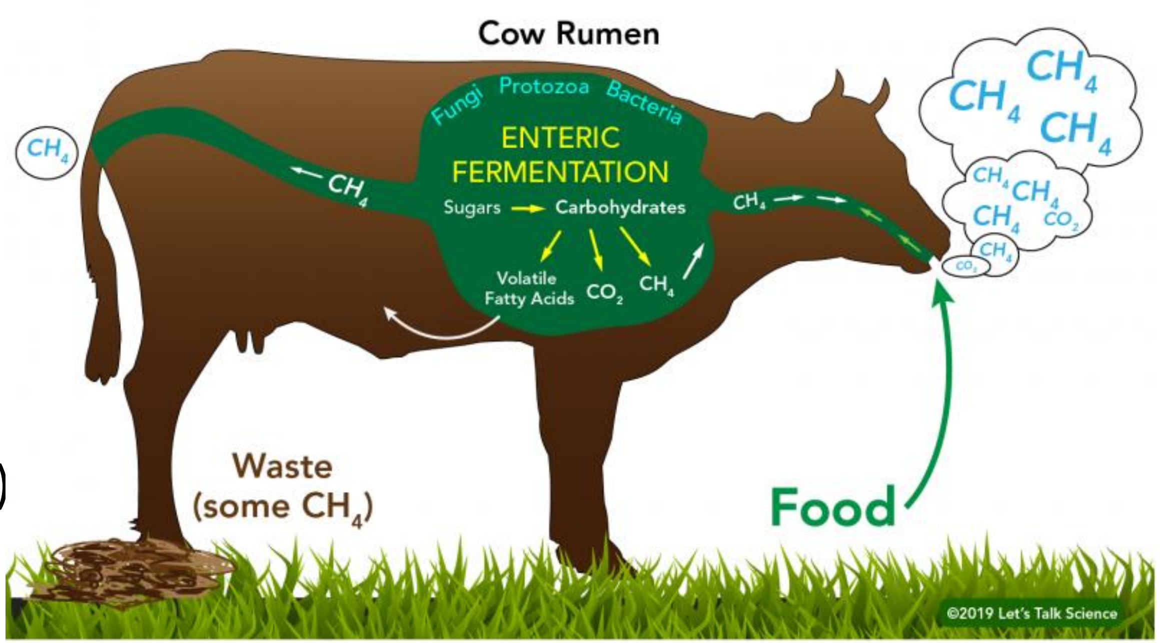
Background and Rationale-Methane

- What is Methane (CH_4)?
  - Greenhouse gas (GHG) produced during fermentation in the rumen
  - Mostly emitted from the mouth (enteric methane)
- Where does it come from?
  - The front end
  - Not the back (1-3%)!
- Why is it important to beef producers?
  - Want to provide the same human nutritional value of food with lower emissions, environmental sustainability
  - Loss of gross energy of feed (2-12%, $$$$)
  - Win-win!



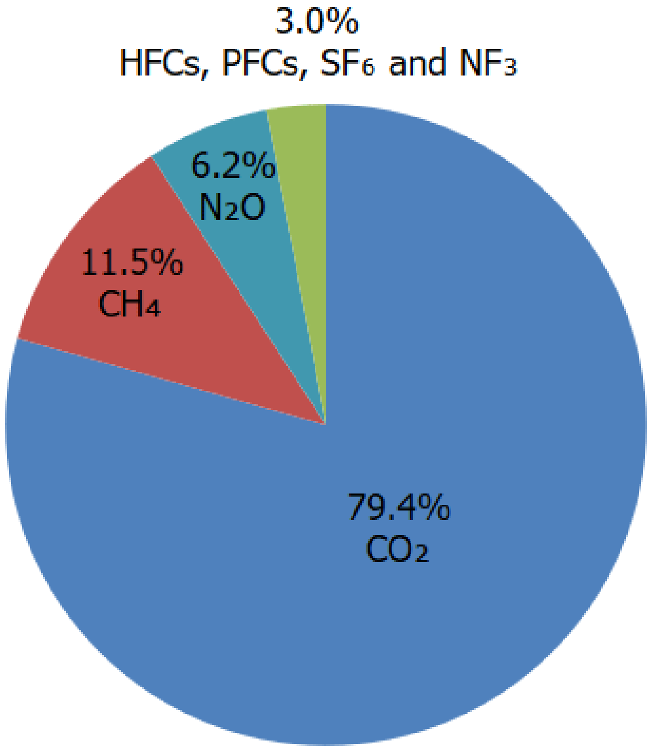
CH_4

Source:
https://en.wikipedia.org/wiki/File:Methane-3D-space-filling.png



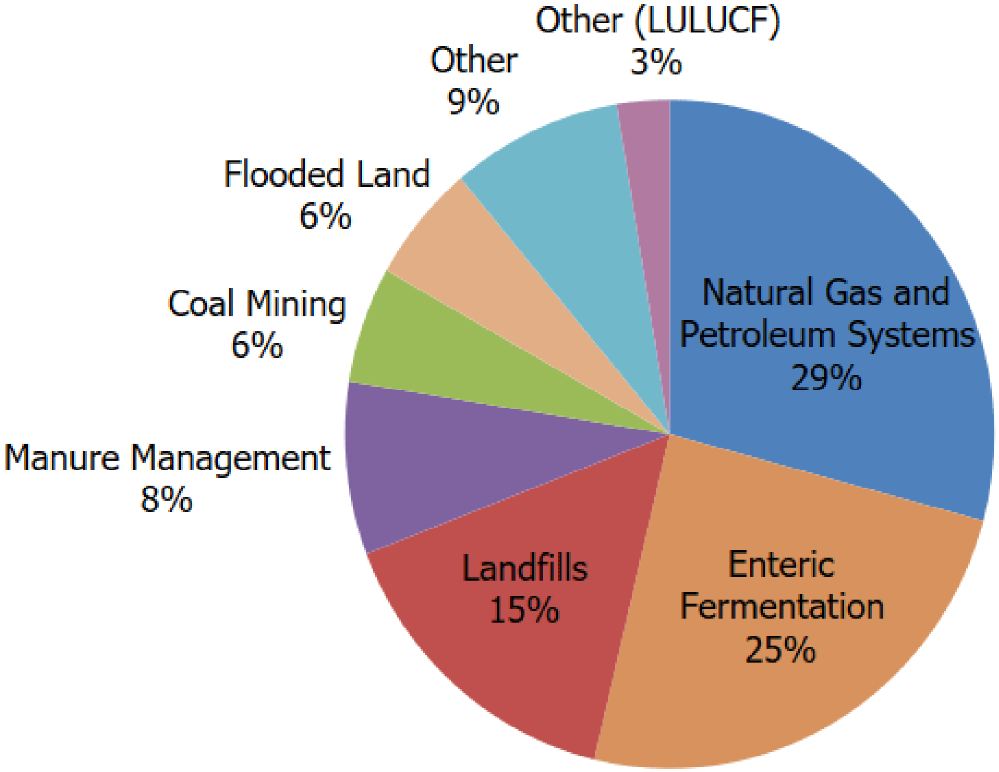
Overview of US Greenhouse Gas Emissions

U.S. GHG Emissions



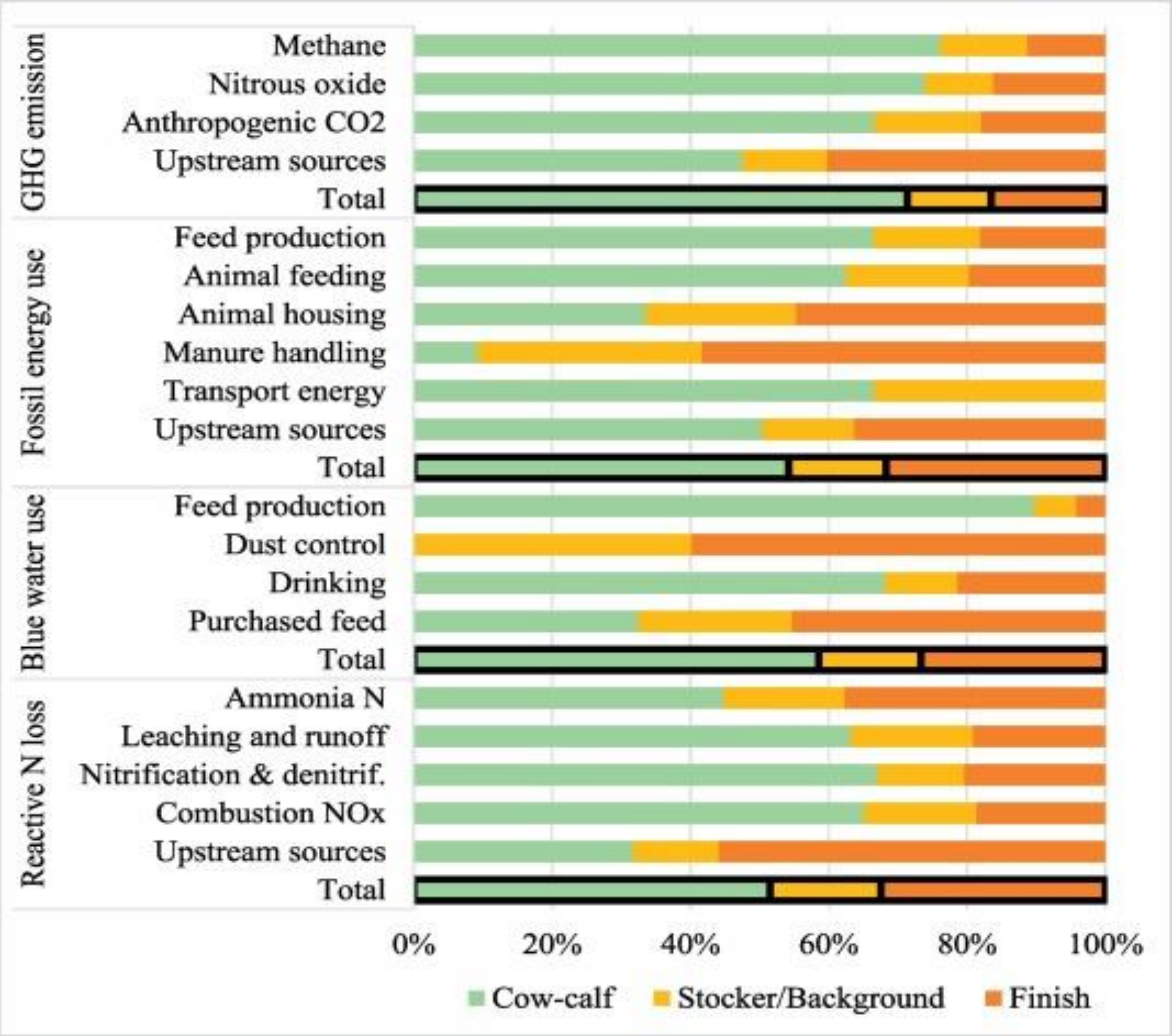
U.S. Environmental Protection Agency (2023). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021

U.S. Methane Emissions, by Source



U.S. Environmental Protection Agency (2023). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021

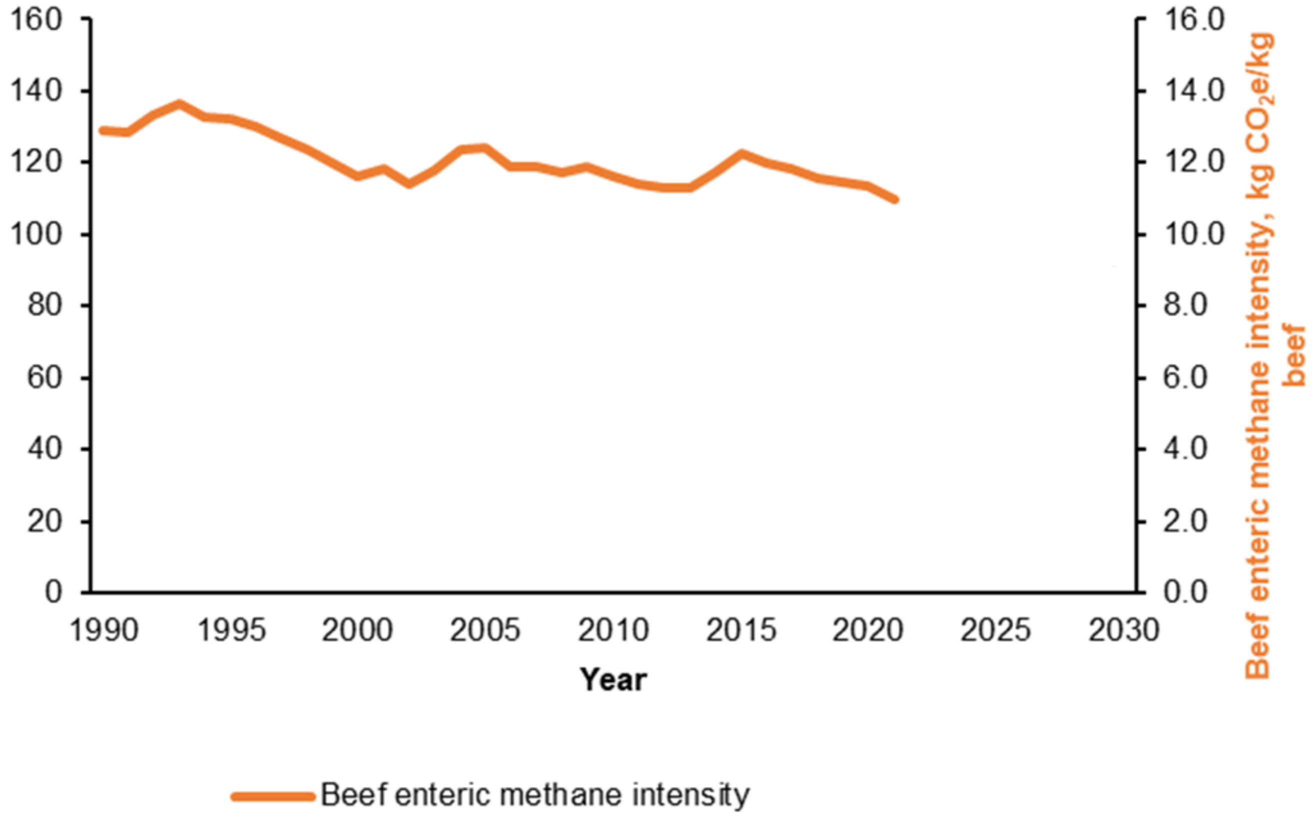
- ~63-80% of total GHG emissions in cradle-to-farm gate life cycle assessments
- Number of animals
  - *Not every cow has a calf each year*
- Diet
  - *Typically, grass-based*
- Lifespan
  - *Majority of lifetime here*
  - *Spend a year in this phase to (hopefully) get one calf*
- The Upside-Upcycling!



(Rotz et al., 2019)

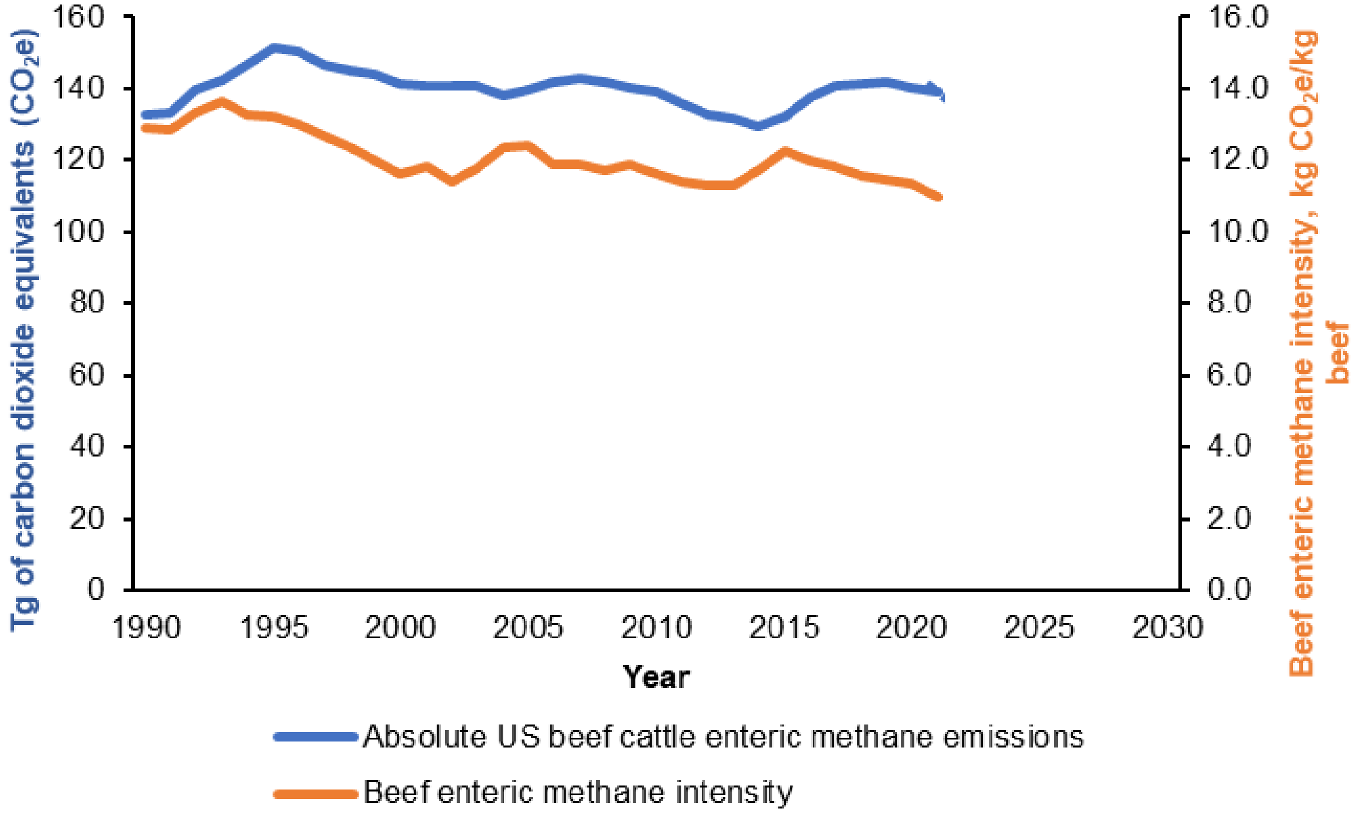
The Good

- Methane intensity (methane/unit beef) has decreased 15% from 1990 to 2021
  - Beef production grew 23%
  - Herd inventory reduced 2%



The Bad

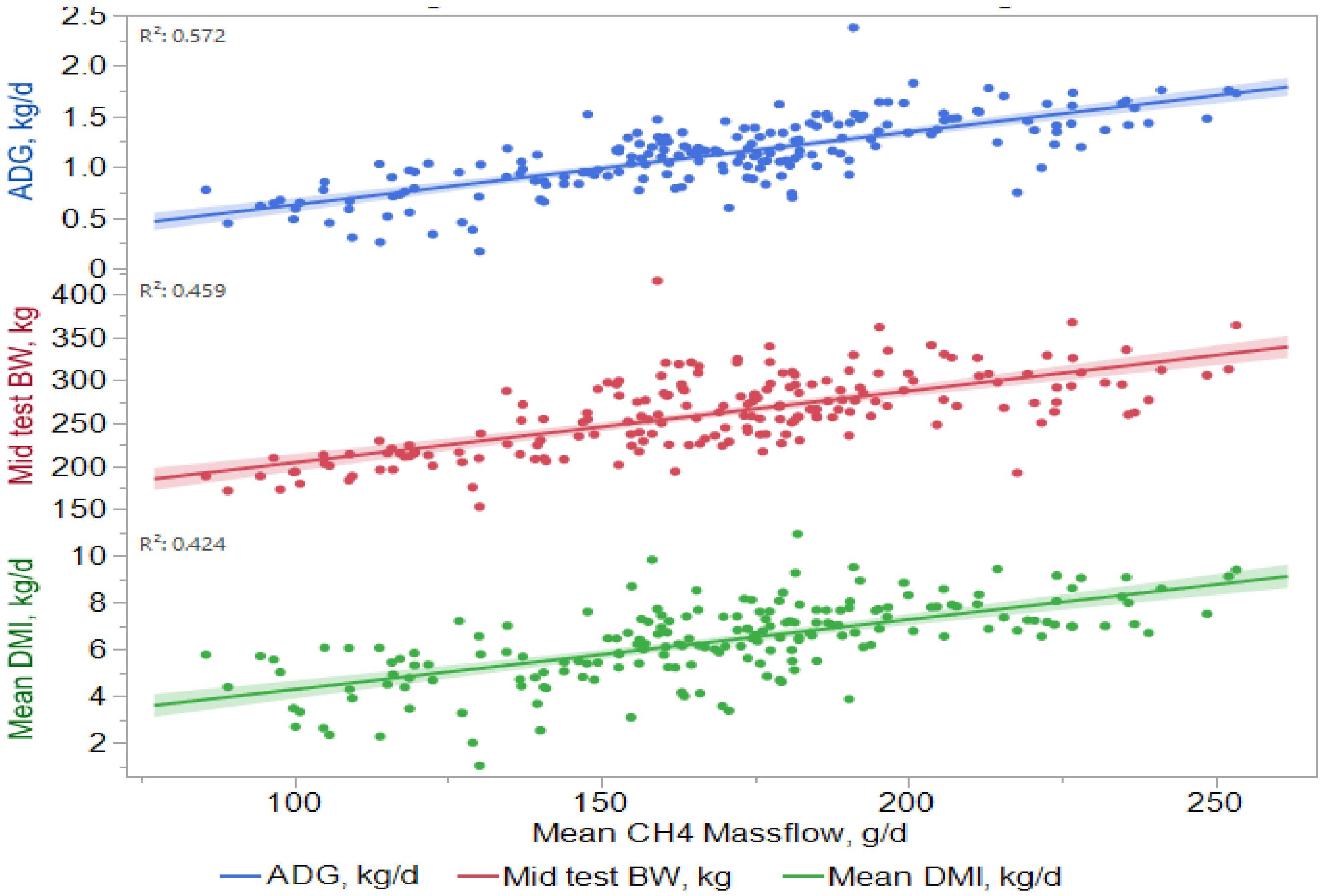
- Overall methane production has actually increased over this time period
  - 5% higher in 2021 vs 1990



Source: US EPA

The Bad

- More productive animals (market signals for bigger, eat more)=more emissions /animal
  - BUT! There is variation here that makes my geneticist heart happy
  - Bigger than methane- can we select for animals that are performers but lower in methane emissions (and maintenance cost)?

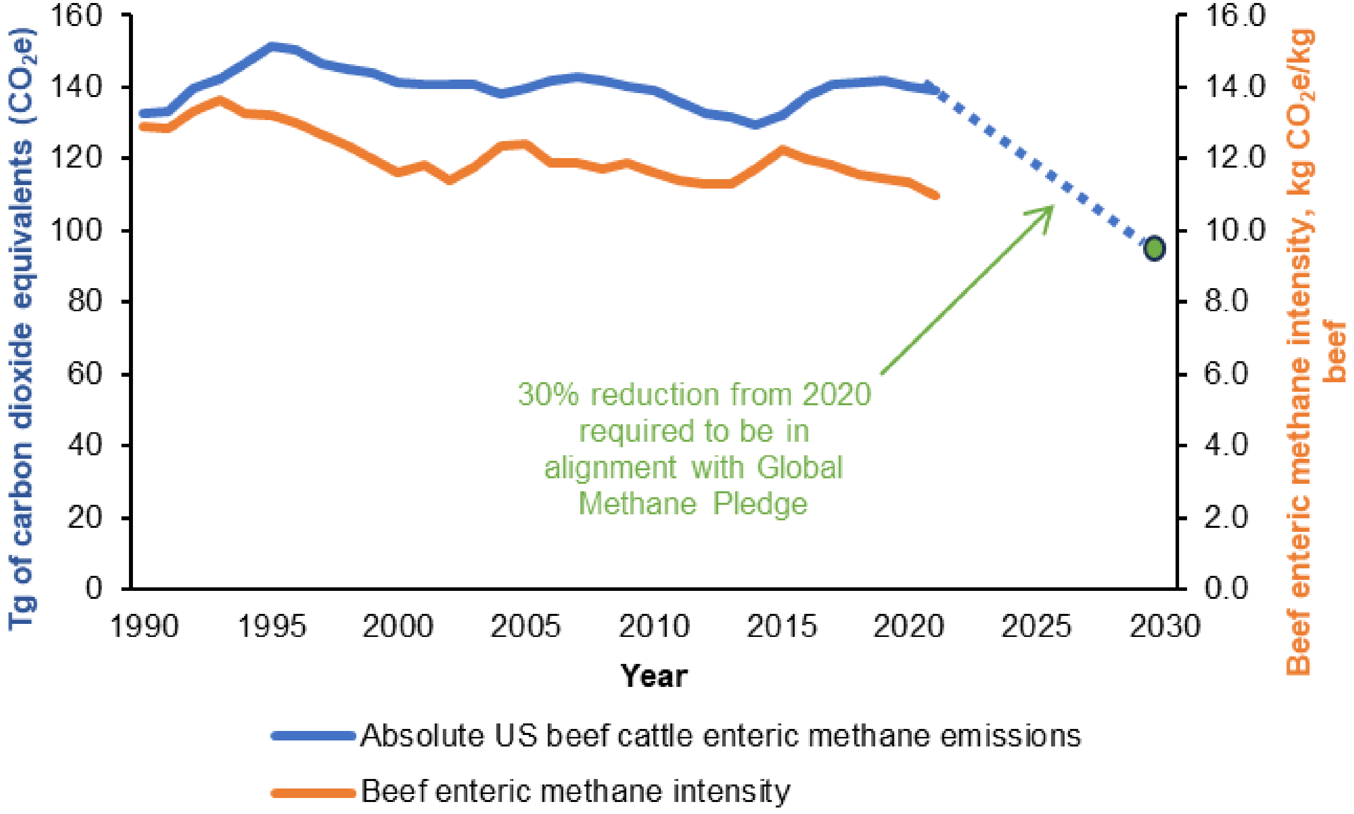


Methane emissions in g/hd/d for cattle (steers n = 99, heifers n = 57, bulls n = 36) fed a high forage backgrounding diet vs dry matter intake (DMI), mid-test body weight, and average daily gain. Data observations collected Nov. 2022 – Jan 2023 at the Climate Smart Research Facility in Fort Collins, CO.

Source: Sara Place, CSU

The Bad

- In order to meet the Global Methane Pledge (30% reduction in methane emissions by 2030 vs 2020), we must reduce methane ABSOLUTE emissions, not intensity
- USRSB and NCBA have set climate neutrality goals by 2040
  - Will require methane reductions
  - Short-lived gas (25 yr half-life), so reductions have more immediate benefit than reductions to CO2 emissions



Source: US EPA

Options to Reduce Methane Emissions

- Ideally, want to improve without sacrificing performance
  - Worst case, find the optimum balance
- 2 Options
  1. Estimate with prediction models
     - What is the relationship between predicted and measured methane outputs?
       - Will be tied to the prediction model

Prediction Models

Andrew Lakamp

- Predicted methane is heritable
  - Take the highly with a grain of salt
- Highly driven by DMI
  - If you know DMI, you've got a good idea of the predicted methane
- Better than nothing, but subject to all of the downsides of models
  - Finding the outliers (modeling the avg)
  - Limited to what you know about other things
  - Finding variation independent of component traits

> J Anim Sci. 2023 Jan 3;101:skad179. doi: 10.1093/jas/skad179.

Variance component estimation and genome-wide association of predicted methane production in crossbred beef steers

Andrew D Lakamp [1], Cashley M Ahlberg [1], Kristi Allwardt [2], Ashely Broocks [2], Kelsey Bruno [2], Levi Mcphillips [2], Alexandra Taylor [2], Clint R Krehbiel [2 3], Michelle S Calvo-Lorenzo [2 4], Chris Richards [2], Sara E Place [2 5], Udaya Desilva [2], Larry A Kuehn [6], Robert L Weaber [1], Jennifer M Bormann [1], Megan M Rolf [1]

Affiliations + expand

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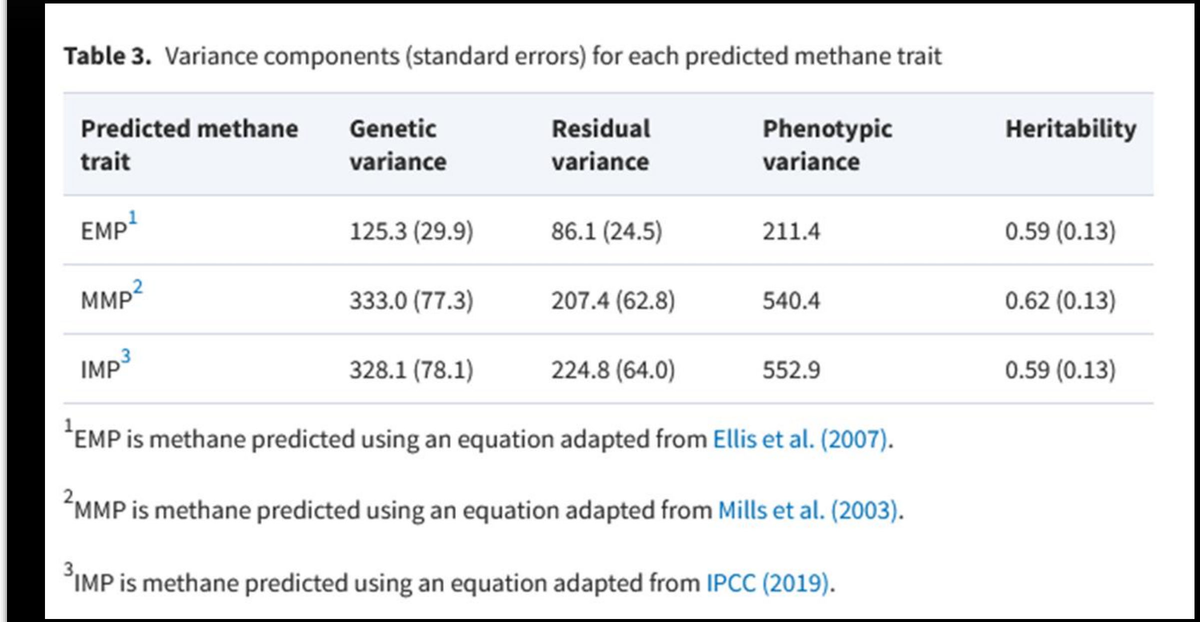


Table 3. Variance components (standard errors) for each predicted methane trait

Predicted methane trait	Genetic variance	Residual variance	Phenotypic variance	Heritability
EMP[1]	125.3 (29.9)	86.1 (24.5)	211.4	0.59 (0.13)
MMP[2]	333.0 (77.3)	207.4 (62.8)	540.4	0.62 (0.13)
IMP[3]	328.1 (78.1)	224.8 (64.0)	552.9	0.59 (0.13)

[1] EMP is methane predicted using an equation adapted from Ellis et al. (2007).

[2] MMP is methane predicted using an equation adapted from Mills et al. (2003).

[3] IMP is methane predicted using an equation adapted from IPCC (2019).

Methane Emissions

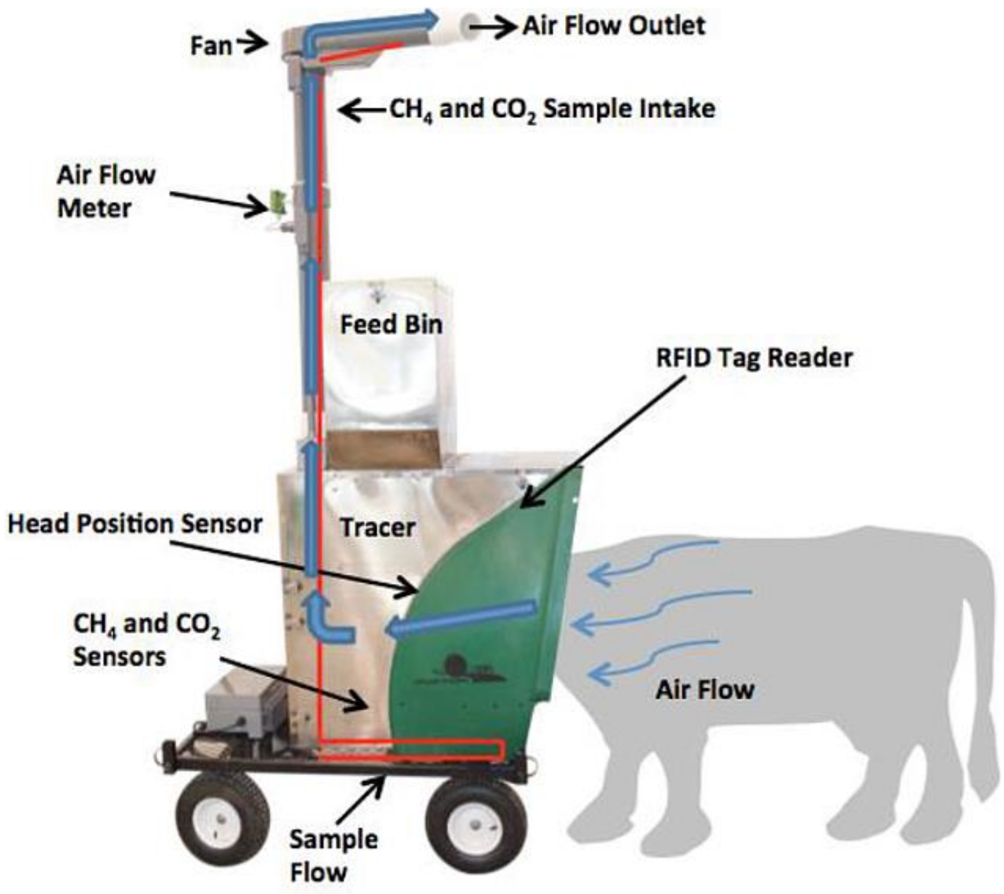
- 2 Options
  1. Estimate with prediction models
     - What is the relationship between predicted and measured methane outputs?
       - Will be tied to the prediction model
  2. Measure it directly
     - Heritable (moderate-Australian/European studies)
     - Confined feeding vs grazing
       - Decent amount of data confined, not much grazing

Measuring Methane Emissions

- Why?
  - No gas flux measures on large numbers of grazing beef cattle in the US
  - No large genetics and genomics studies of methane production of grazing beef cows in the US
  - Currently, no genetic evaluation systems in the US incorporate methane production phenotypes to produce expected progeny differences (EPDs) for beef producers
- Several options
  - Limitations if want to target grazing animals

The GreenFeed System (C-Lock, Inc.)

- Open-circuit gas quantification system
- Unencumbered
- $CH_4, CO_2,$ optionally O_2, H_2
  - More on this later
- Ideally, several spot samples collected throughout the day



With These Measurements

[1] $OMI = 12.5 - 0.0299W + 0.00002W^2 - 0.05531D + 0.00032W \times D$

[2] $OMI = 251 - 0.06W + 0.00008W^2 - 7.6D + 0.062D^2 - 265G + 8.7G \times D - 0.07G \times D^2$

[3] $OMI = 266 - 0.08W + 0.00009W^2 - 8.1D + 0.067D^2 - 1.06WW + 0.036WW \times D - 0.00029WW \times D^2$

- Do not HAVE to have DMI to predict CH4
  - Grazing work is now possible (can predict DMI with these values)
- Can be included in Index development
  - What traits get included?
- ID and/or select on variation independent of other traits
  - DMI and/or index
- Value-added approach
  - With addition of Oxygen and CO2 (ignoring N), can calculate heat production (proxy for metabolic rate/maintenance energy)
  - Can calculate estimated forage intake (also need weight, ADG and/or calf WW)

$$HP\ (Mcal/day) = 3.866 \times O_2(L) + 1.2 \times CO_2(L) - 0.518 \times CH_4\ (L) - 1.431 \times N_{urine}\ (g)$$

Background

- Length of trial period or total number of spot sample visits?
- Most research has looked at length of trial period (d) for CH4 measurement (mostly in confined animals/dairy)
  - Renand and Maupetit (2016): 2 weeks or 50 spot samples (confinement)
  - Arbre et al. (2016): 17 days (dairy)
  - Gunter and Beck (2018): 14 days if avg. 2.5 visits/day (grazing)
  - Arthur et al. (2017): 30 records (feedlot)

Objective 1

- To determine the minimum number of spot samples required to accurately estimate CH_4, CO_2, and O_2 gas fluxes and metabolic heat production from an individual grazing beef cow

Animals and Protocol

- Mature Angus beef cows from KSU PBU
  - Collection May 23rd to Sept. 9th 2021
  - 2-week acclimation
- 23 animals
  - 20 animals used system (13% refusal)
  - 17 animals with 100+ spot samples
- 25 g dropped every 30 sec up to 8 times
- Allowed 5 visits a day with minimum 2 hr between

Our GreenFeed-Built for Larger CGs

Phenotypes Analyzed

- $\mathrm{CH_4}$
- $\mathrm{CO_2}$
- $\mathrm{O_2}$
- Metabolic Heat Production

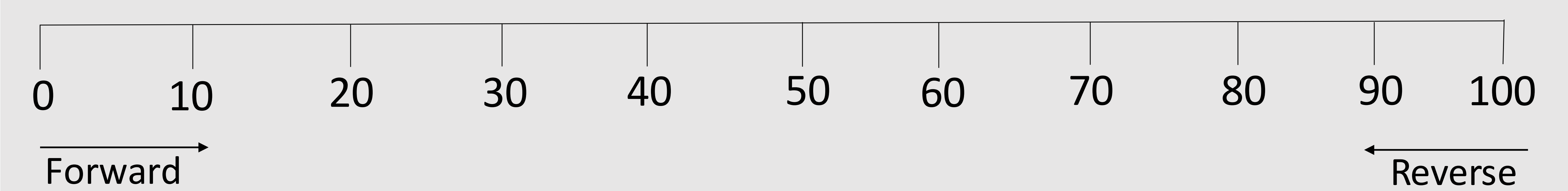
$$HP(\frac{kcal}{day}) = 3.866 * O_2(\frac{L}{d}) + 1.2 * CO_2(\frac{L}{d}) - 0.518 * CH_4(\frac{L}{d}) - 1.431 * N(\frac{L}{d})$$

- Very small energy loss to urinary-N omitted

Simonson and DeFronzo, 1990

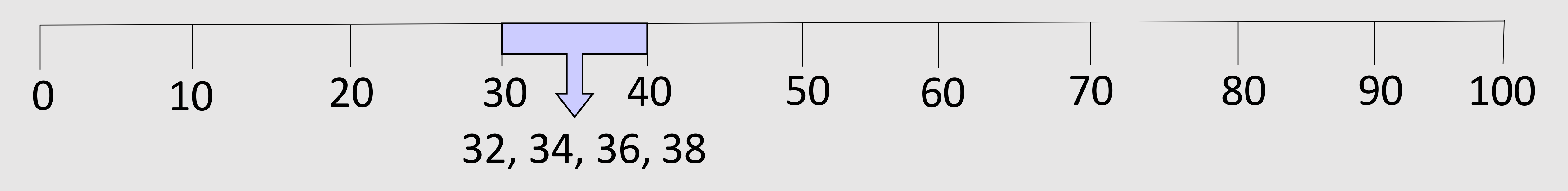
Data

- Created spot sample intervals that increased incrementally by 10 visits starting with the first 10 visits- “Forward”
  - F10, F20, F30, F40, F50, F60, F70, F80, F90, F100
- … starting with the last 10 visits- “Reverse”
  - R10, R20, R30, R40, R50, R60, R70, R80, R90, R100
- Calculated mean gas flux for each animal and interval
- Using interval mean gas fluxes, calculated metabolic heat production



Data

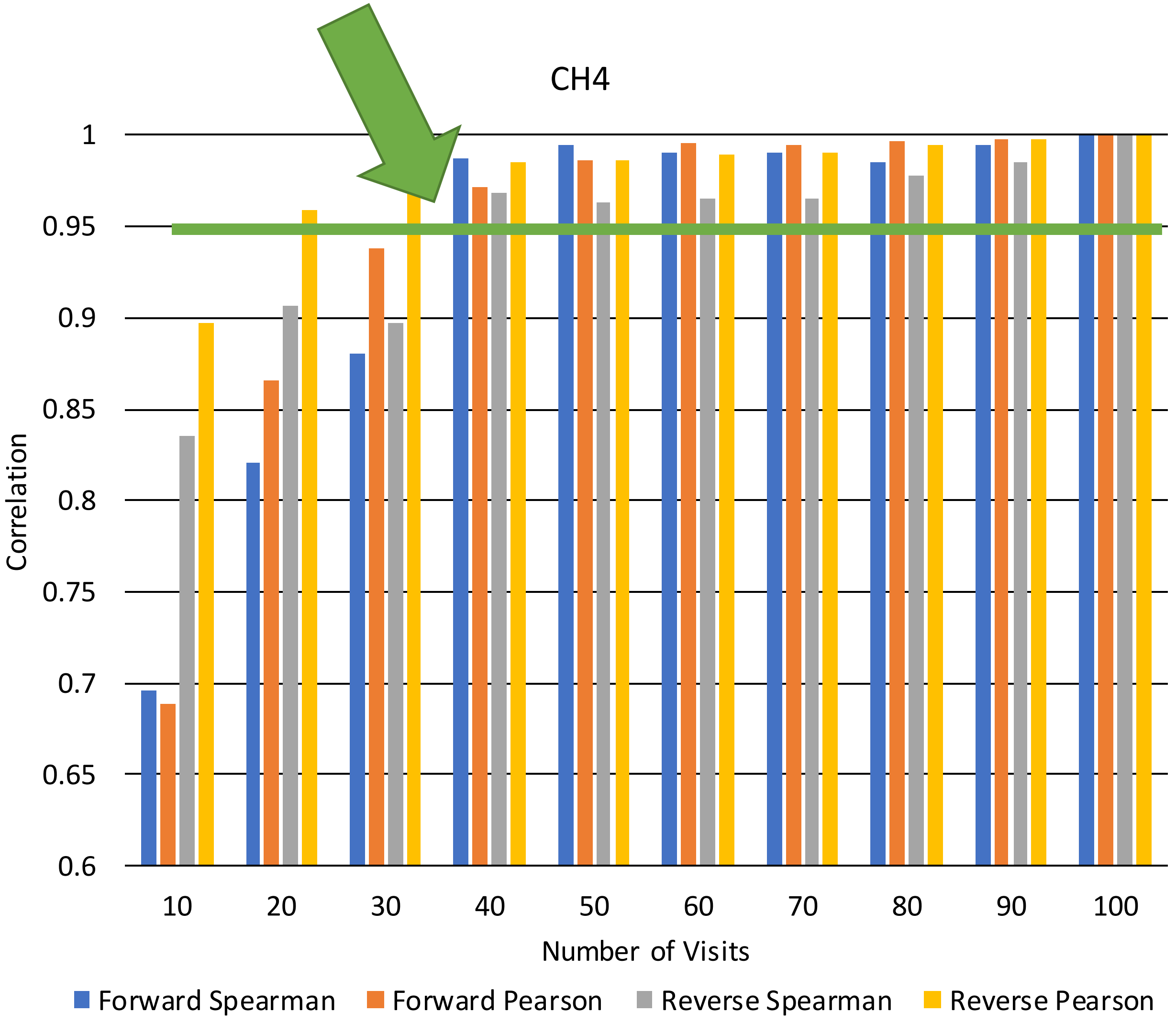
- Calculate Spearman and Pearson correlations between full 100 spot samples and each shortened interval
- Split 30 to 40 visit interval further into increments of 2
  - F30, F32, F34, F36, F38, F40
  - R30, R32, R34, R36, R38, R40
- Spearman and Pearson correlation between the full 100 visits and the shortened increments
- Recommended number of spot samples achieved when correlation >0.95

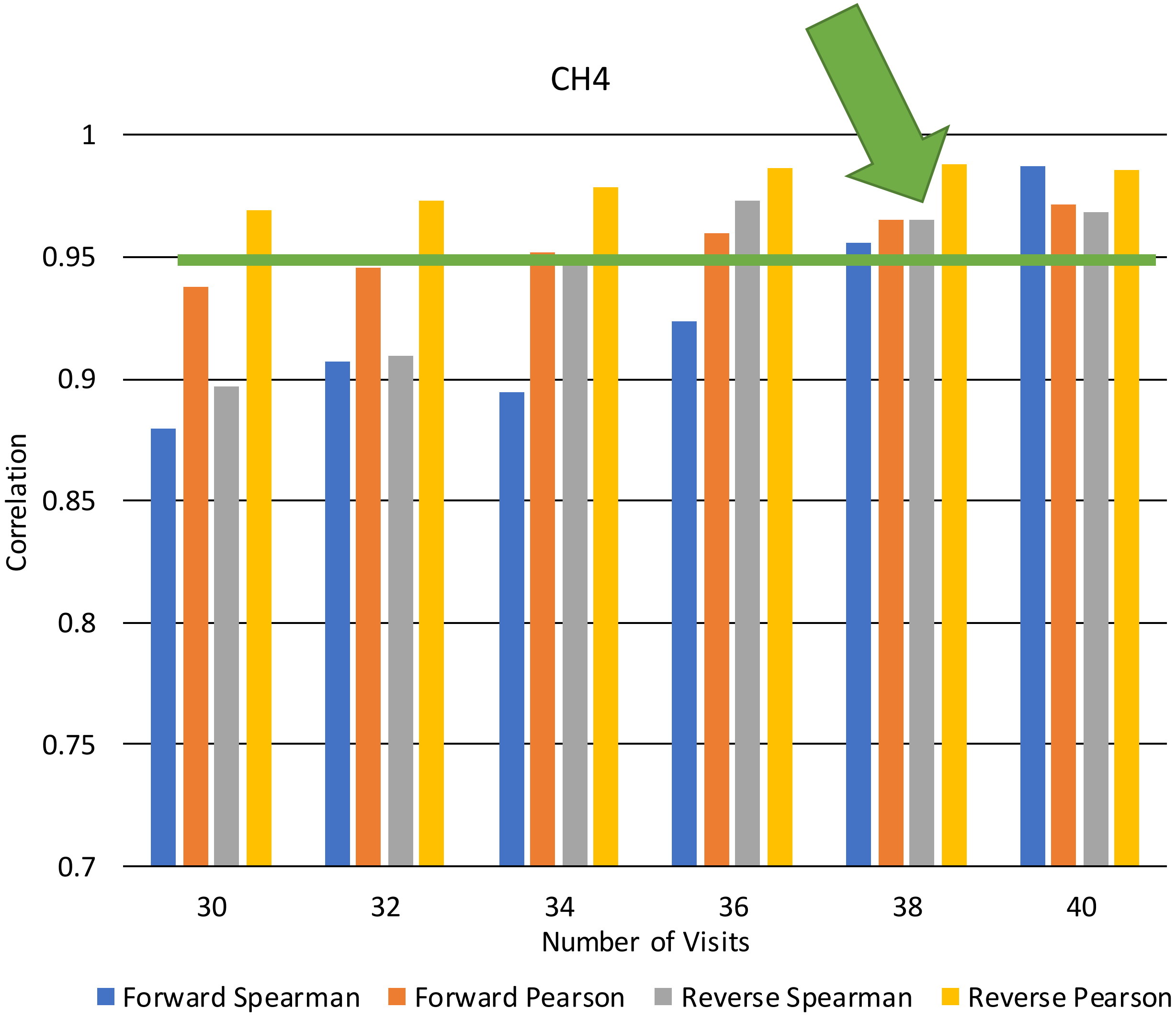


Descriptive Statistics

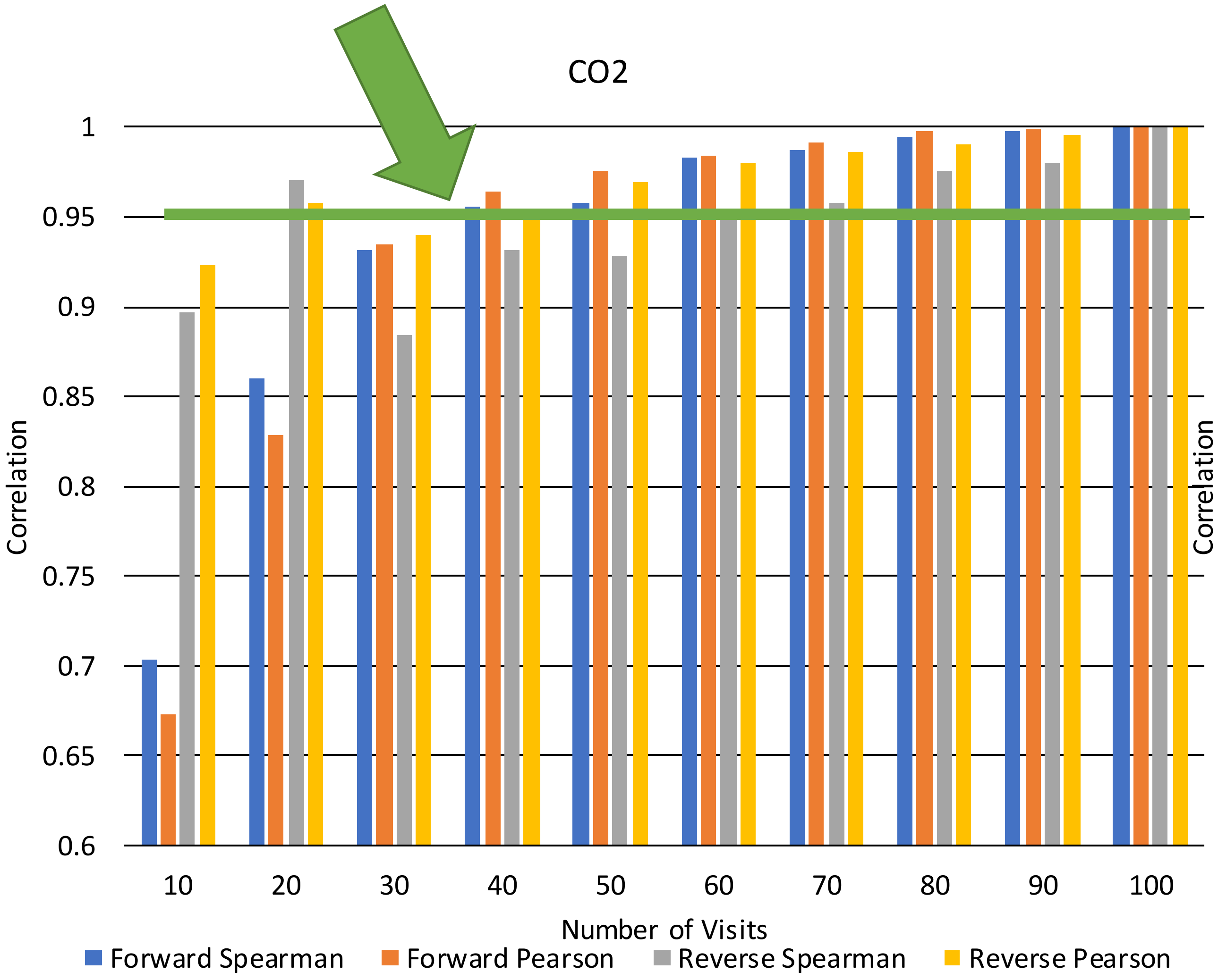
	n	Mean	Minimum	Maximum	Standard Deviation
CH_4, g/d	17	353.8	106.0	599	83.7
CO_2, g/d	17	10,428.1	5,585	14,996	1,754.7
O_2, g/d	17	7,713.2	3,913	11,629	1,325.1
Metabolic Heat Production, kcal/d	17	27,278.2	22,068.2	32,391.3	3,089.2

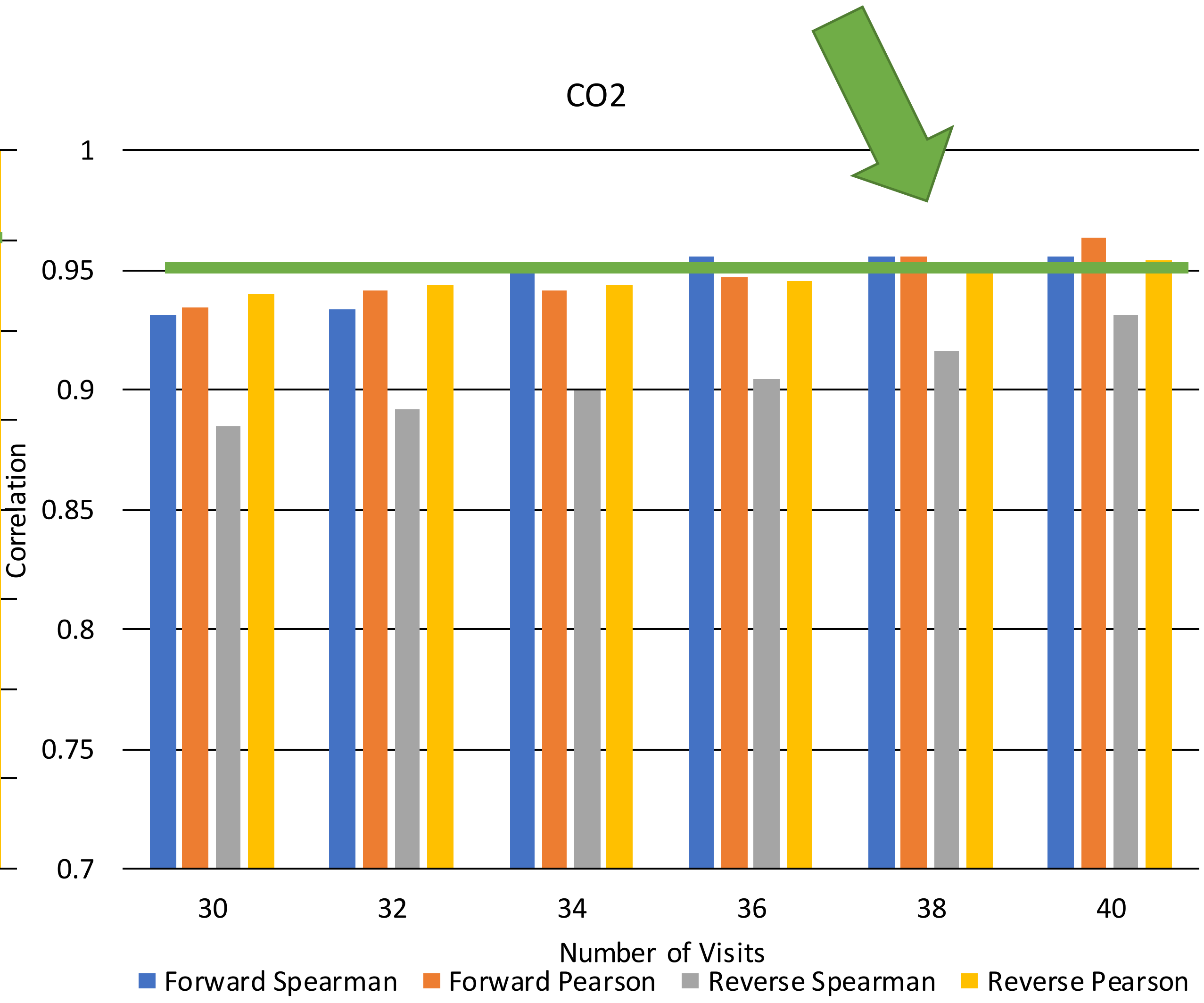
Recommended Spot Samples- CH_4



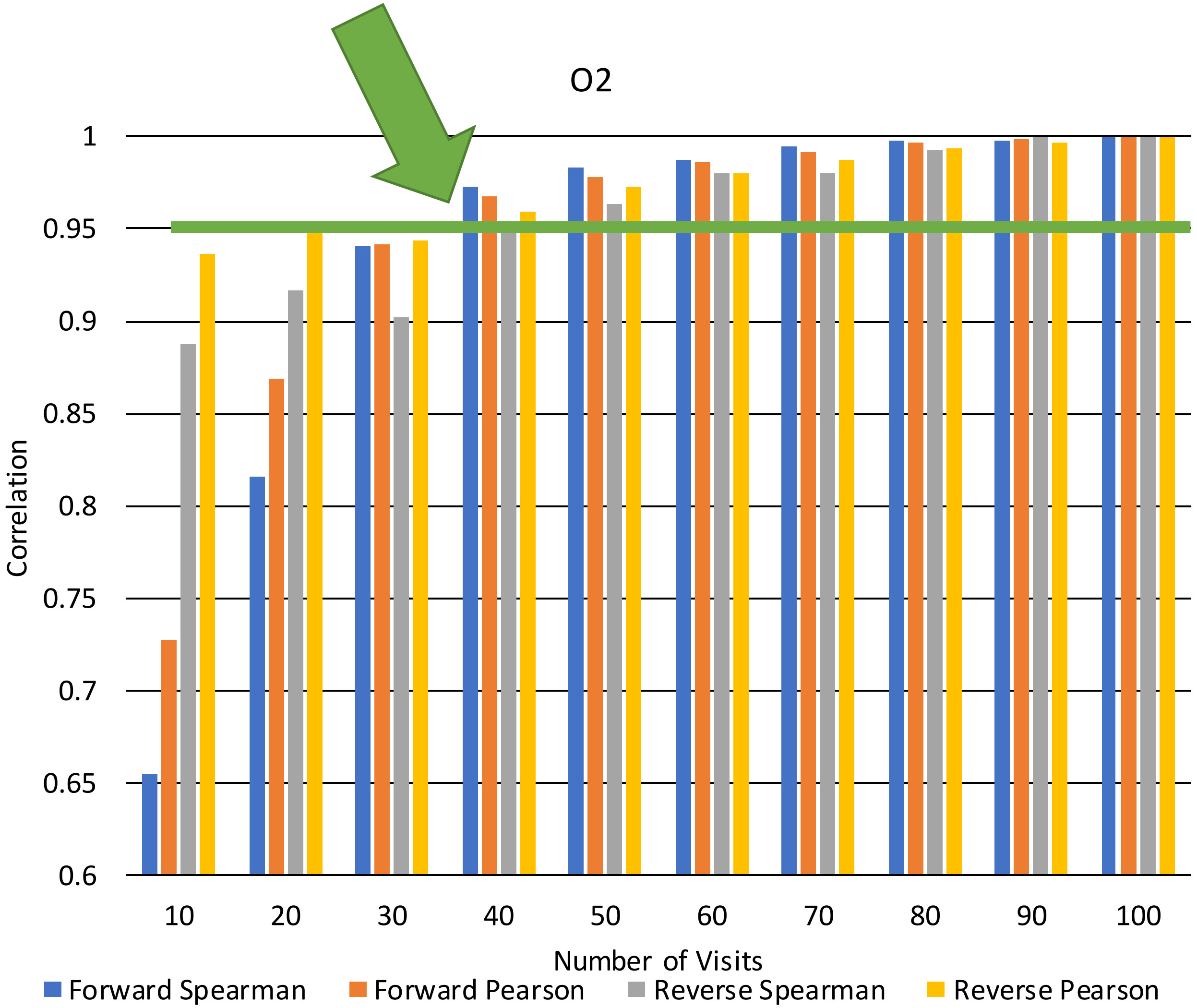


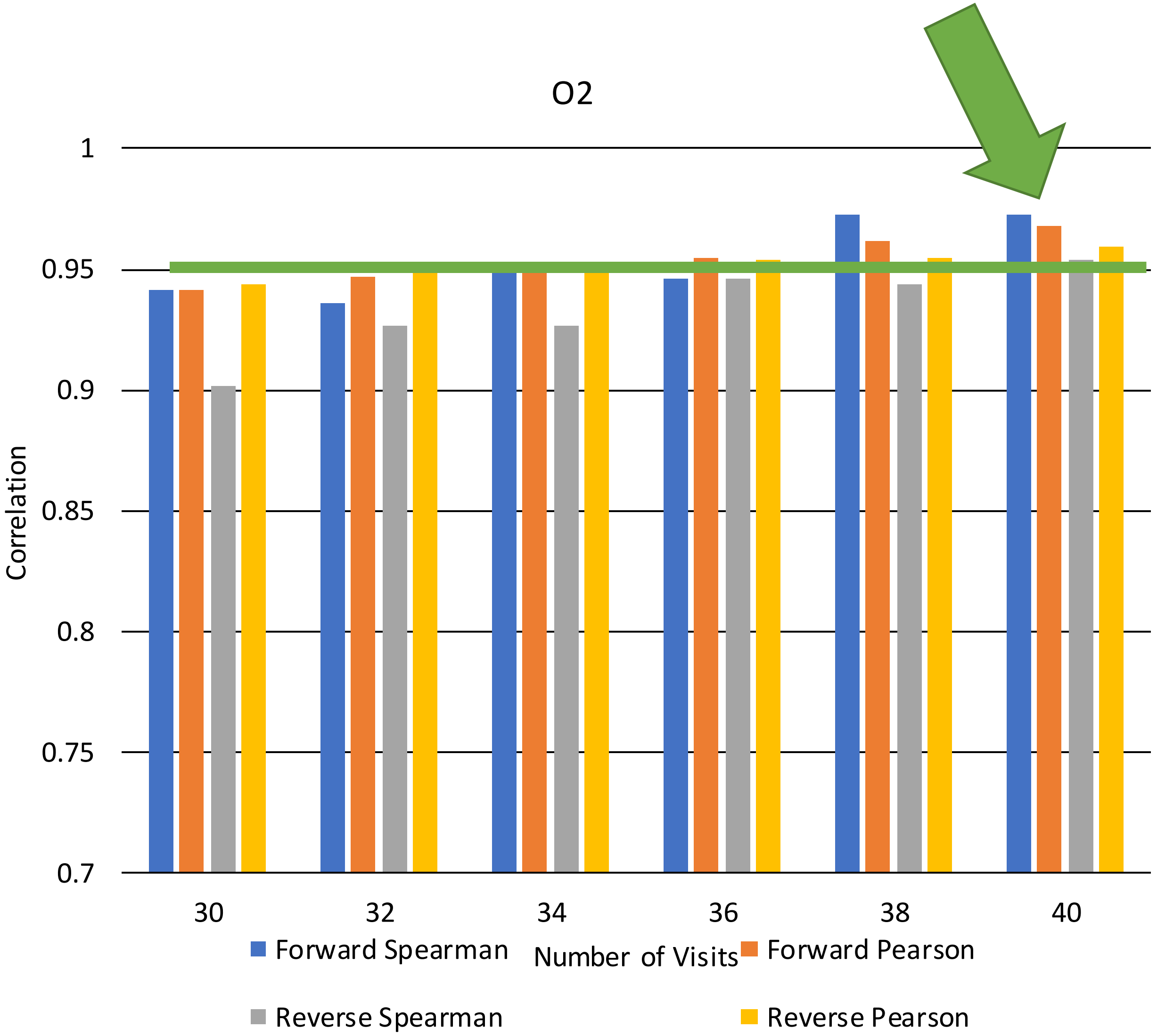
Recommended Spot Samples- CO_2



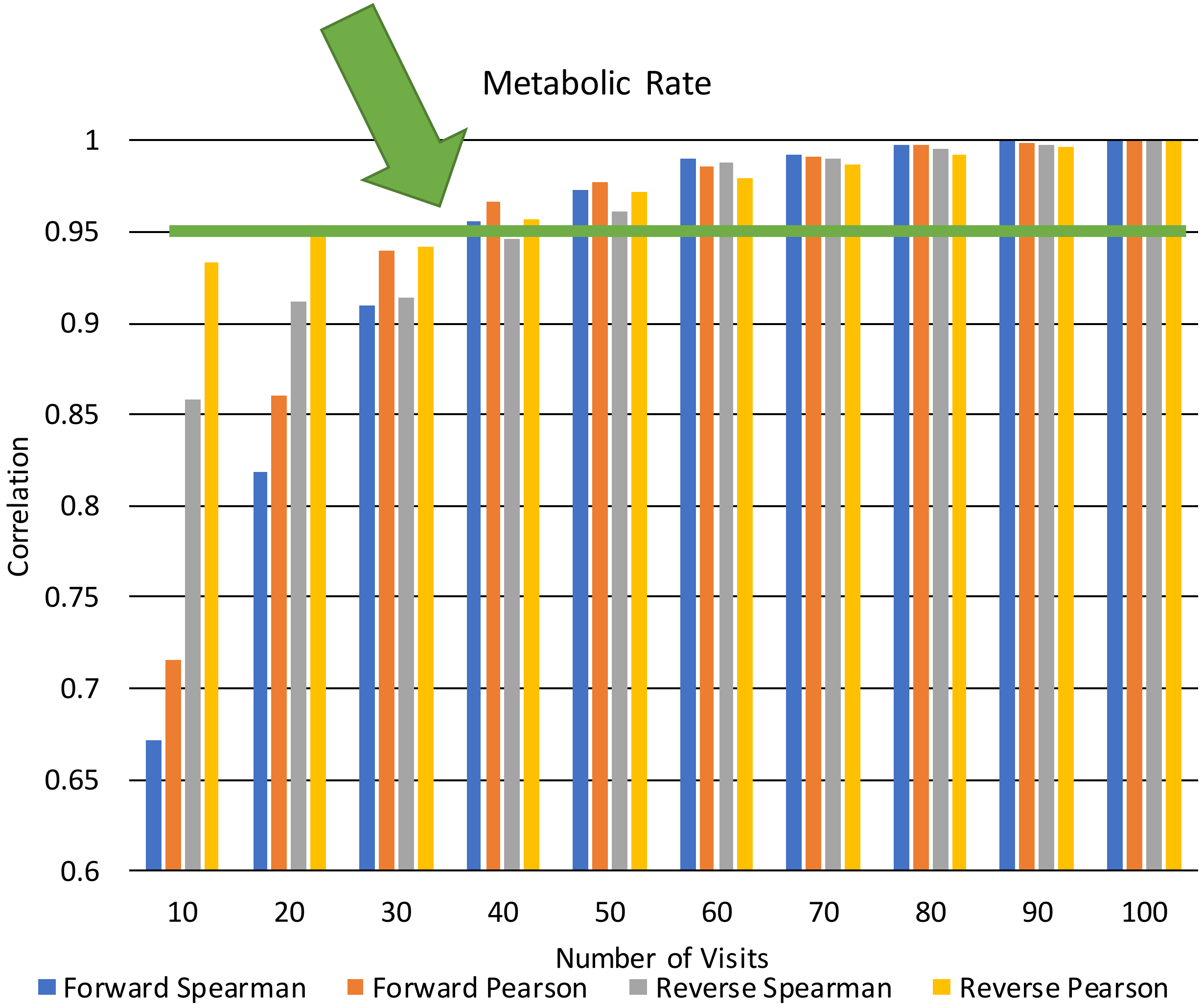


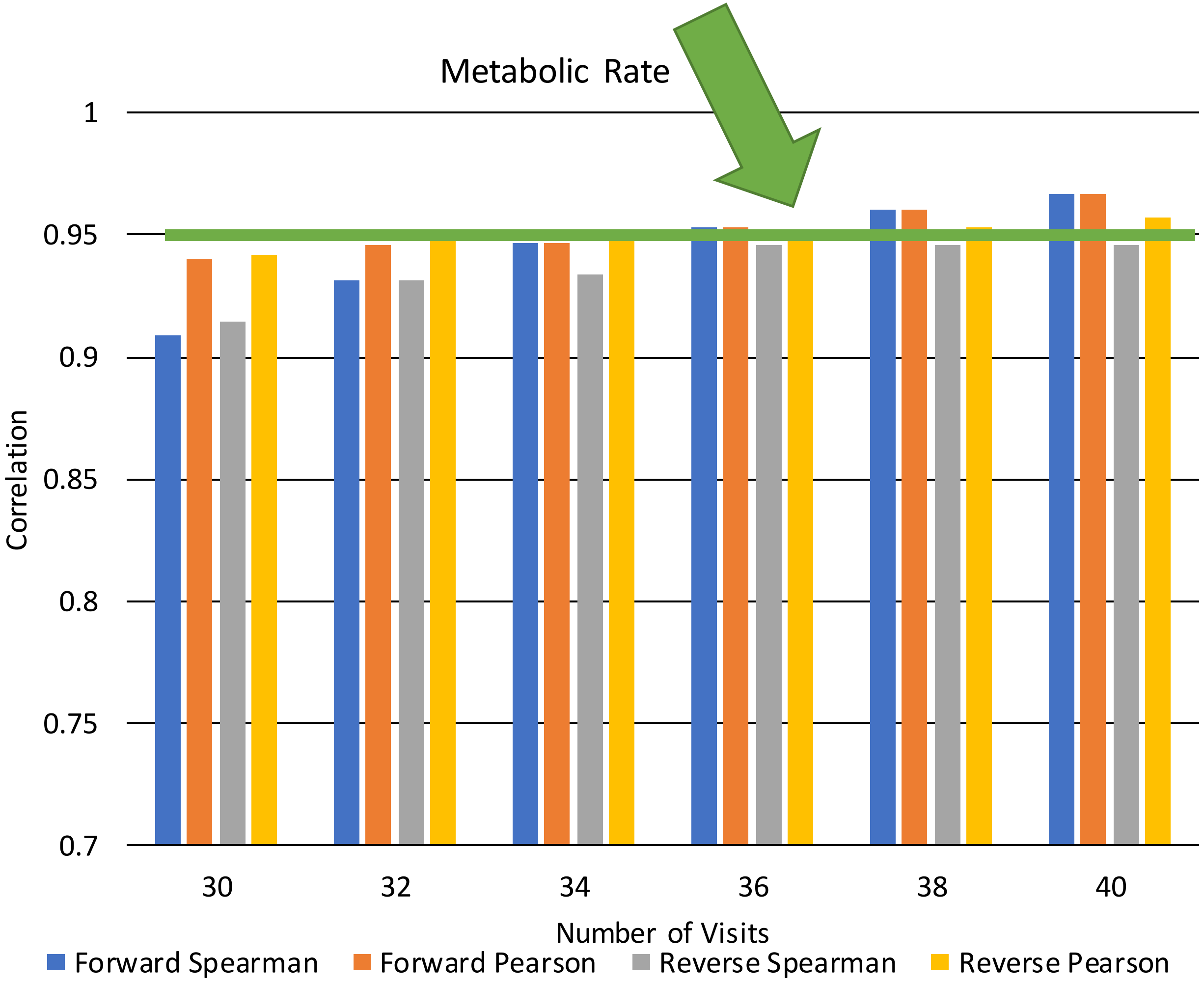
Recommended Spot Samples- O_2





Recommended Spot Samples- HP



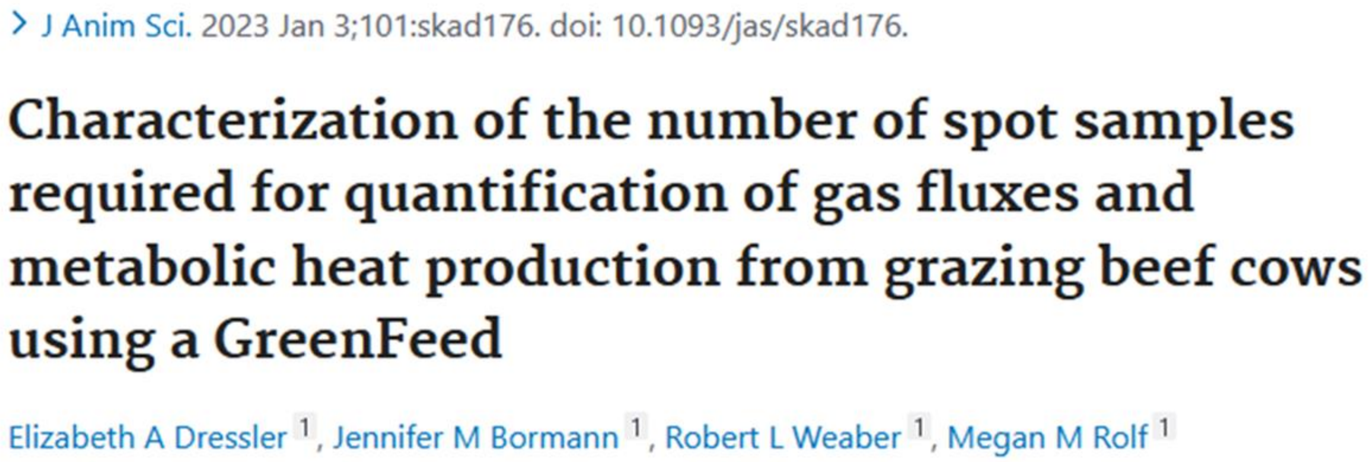


Conclusions

- Number of Spot Samples Recommended-
  - CH_4: 38
  - CO_2: 40
  - O_2: 40
  - Metabolic Heat Production: 36
- Number of Spot Samples vs. Number of Days-
  - CH_4: 29.5±8.7 days
  - CO_2: 30.5±9.1 days
  - O_2: 31.8±9.2 days
  - Metabolic Heat Production: 29.5±8.7 days
- Protocols should include # of spot samples rather than test duration

Published Paper Information

Scan for direct link!



› J Anim Sci. 2023 Jan 3;101:skad176. doi: 10.1093/jas/skad176.

Characterization of the number of spot samples required for quantification of gas fluxes and metabolic heat production from grazing beef cows using a GreenFeed

Elizabeth A Dressler [1], Jennifer M Bormann [1], Robert L Weaber [1], Megan M Rolf [1]

Challenges

- We know why people haven’t done tons of this
  - HARD!
  - Takes a long time
  - Expensive
  - Equipment malfunctions

- Can this be implemented in industry?
  - As-is?
  - Can we extend these data to more animals (“incomplete” records)?
  - Is grazing the same as confinement?
  - Does it matter when we measure-growing or mature?

We’ve Continued to Collect Data

- Includes data from 3 locations
- All validated visits
- Some animals have less than 40 visits (these have >5)
- Currently collecting data in a group of 100, ~60 using regularly

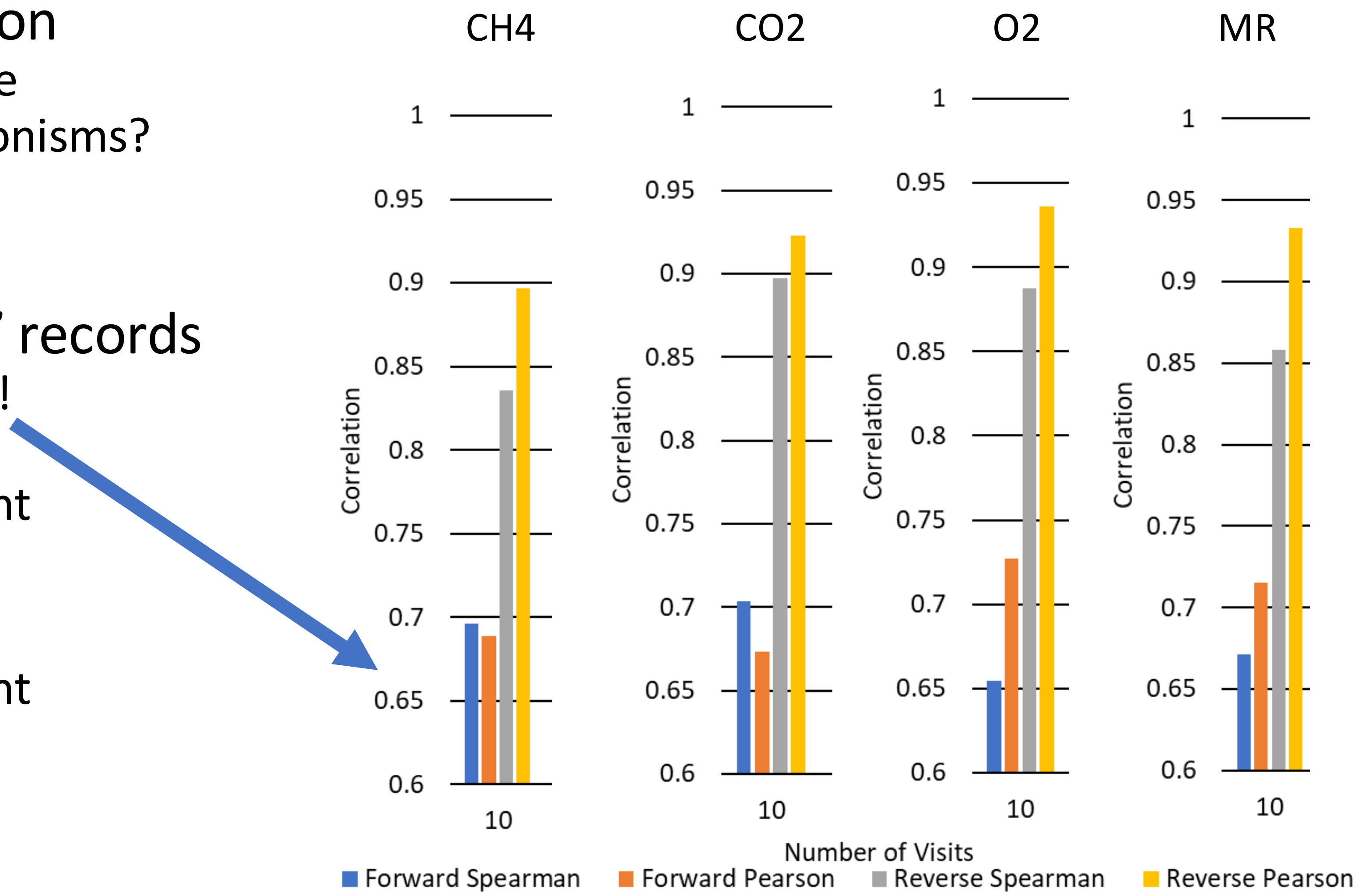
Gas	n	Min	Mean	Max	sd
CH4	74	33.0	323.5	667.6	97.26
CO2	74	3147	9748	14996	1951.83
O2	74	2191	7150	11629	1472.59

Objectives 2-?: The Future

- Prototype genetic evaluation
  - Univariate then multivariate
  - Genetic correlations/antagonisms?
  - QTL analysis

- Utilization of "incomplete" records
  - Even one visit is ~0.45-0.55!
  - Methodology TBD
  - Proposal under development

- Index development?
  - Proposal under development



Acknowledgments

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- Bob Weaber and Jenny Bormann

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  - Shane Werk and the PBU staff
  - Dave Nichols
  - Matt Perrier and Dalebanks Angus
  - Hopefully many more in the future!

Acknowledgments

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ANGUS
Foundation

- This work was supported by the NAAB Doak Graduate Fellowship

NAAB
National Association
of Animal Breeders

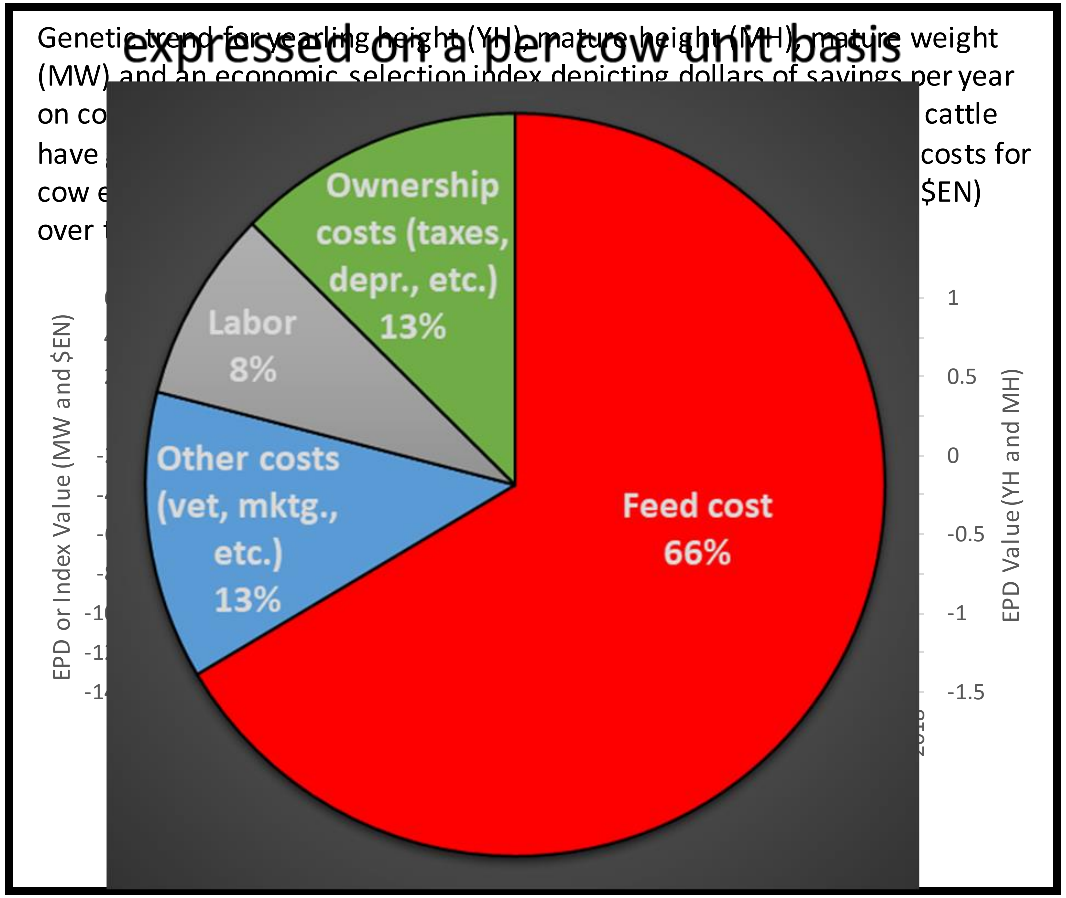
- Countryside Feeds, LLC in Seneca, KS for the donation of feed for this project

COUNTRYSIDE
FEED LLC

Another Motivation!

- Measurement of metabolic rate
  - Energy expenditure (calories) of animals per unit time
  - Reflects amount of feed required to maintain basic activities and functions
- Where are the impacts?
  - In the cow/calf sector
    - Over time, the beef industry has increased milk production, mature size and weight, (which increase maintenance energy required). Estimated cow energy requirements have also increased (genetic trends).
    - Metabolic rate + productivity measures provides insight into maintenance costs and efficiency of beef production
- Why is it important to beef producers?
  - Maintenance energy is 70 to 75 percent of the total energy consumed by the cow herd (Ferrell and Jenkins, 1985)
    - On average, >50% of cow cost is feed
  - No direct selection tools on metabolic rate
    - Maintenance energy in Red Angus
      - Predictions based on size and milk yield
    - $EN Index (Angus)
      - Also based on size and milk yield

Estimated annual cow costs expressed on a per cow unit basis



Source: Estimated annual cow costs for Nebraska, 2017 https://beef.unl.edu/documents/marketing-budget/Estimated-Annual-Cow-Costs-Nebraska-2017.pdf