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SHAPING THE FUTURE OF SUSTAINABILITY IN ANIMAL AGRICULTURE

FIVE RIVERS
CATTLE FEEDING

Antitrust Statement

It is expected that the meeting today be conducted in a manner that complies with all applicable state and federal anti-trust laws. In general, the types of discussions that must not occur are those that may suggest or imply agreements among competitors with respect to: pricing, terms of sale, credits, discounts, or any other such items that could impact prices. Other topics that must be avoided include the allocation of customers; markets or territories; bid-rigging; and group boycotts or joint refusals to do business with others; or any discussion or activity that may be construed as forestalling research and development. If at any time during this meeting a participant believes that a subject with any anticompetitive implication or appearance has been raised, they should object and request that the subject be dropped.

Joyce McConnell
President, CSU

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Mike Thoren
President & CEO,
Five Rivers

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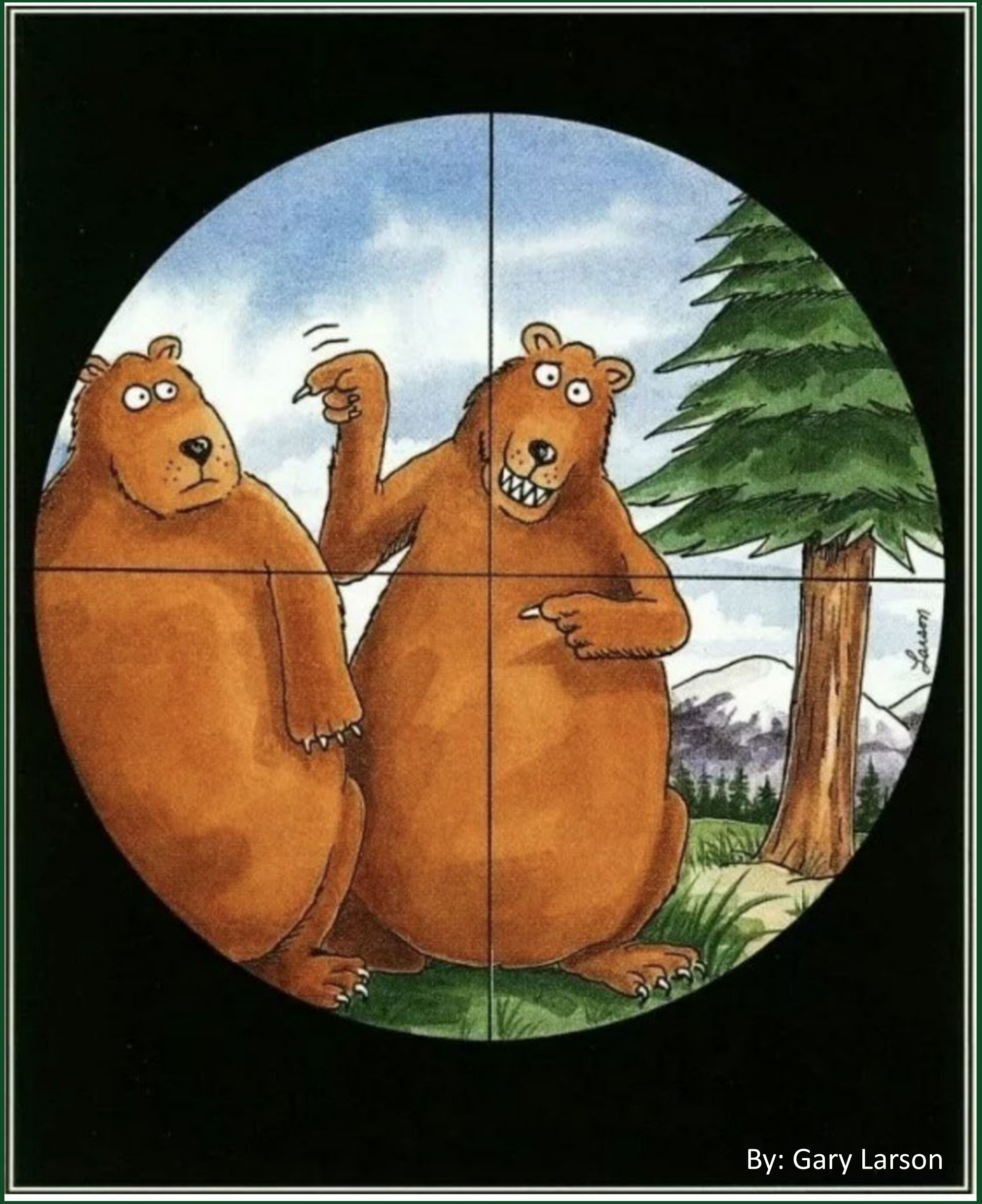
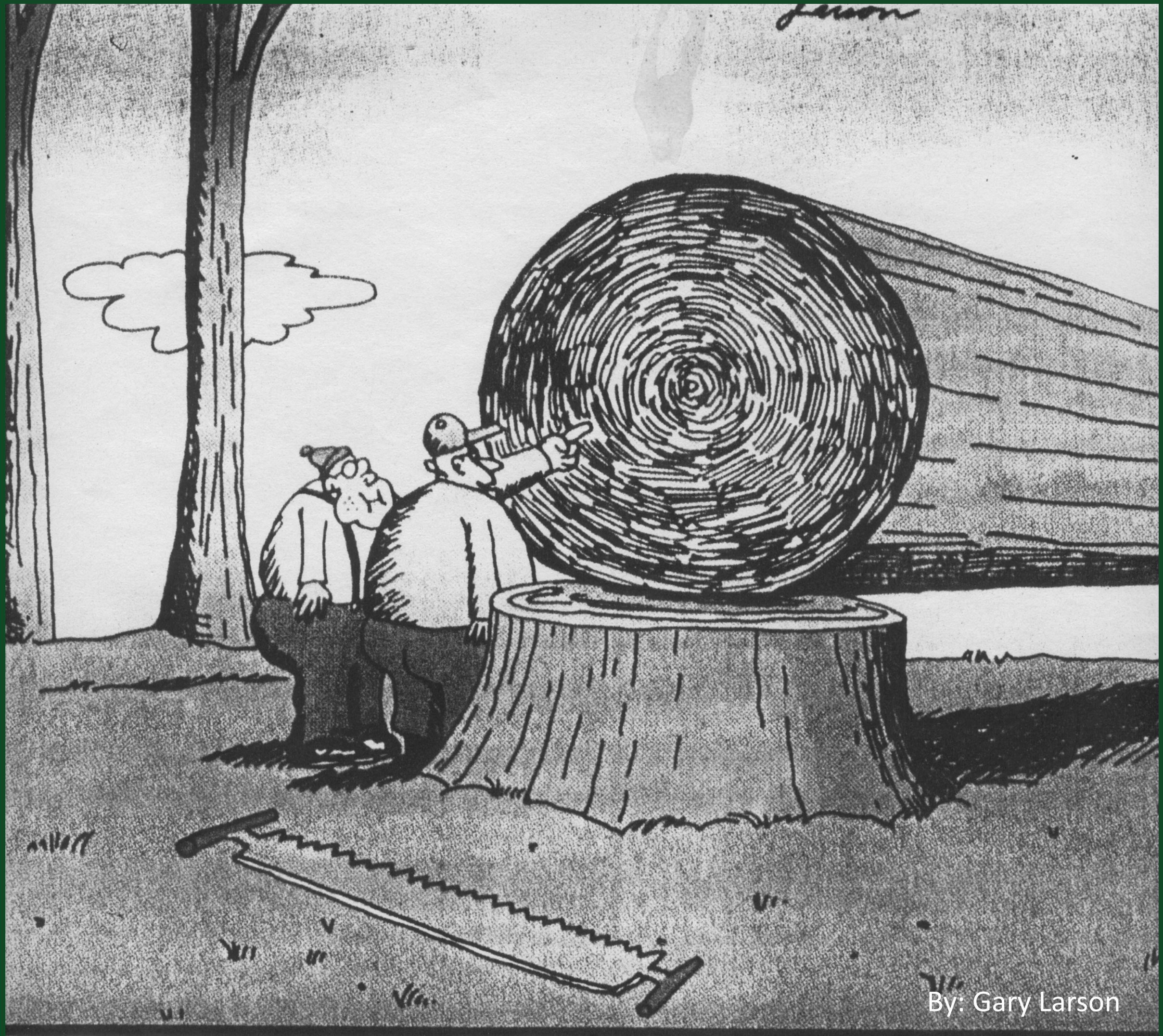
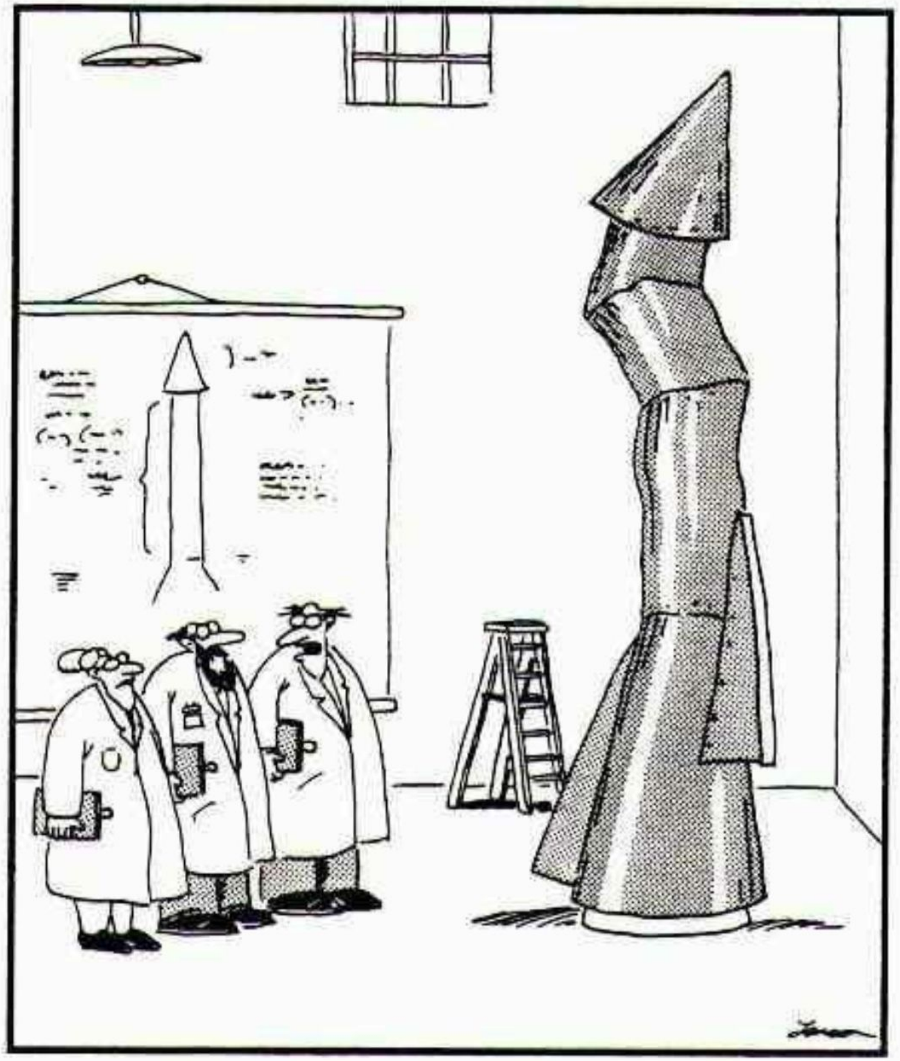
"Bummer of a birthmark, Hal."



By: Gary Larson

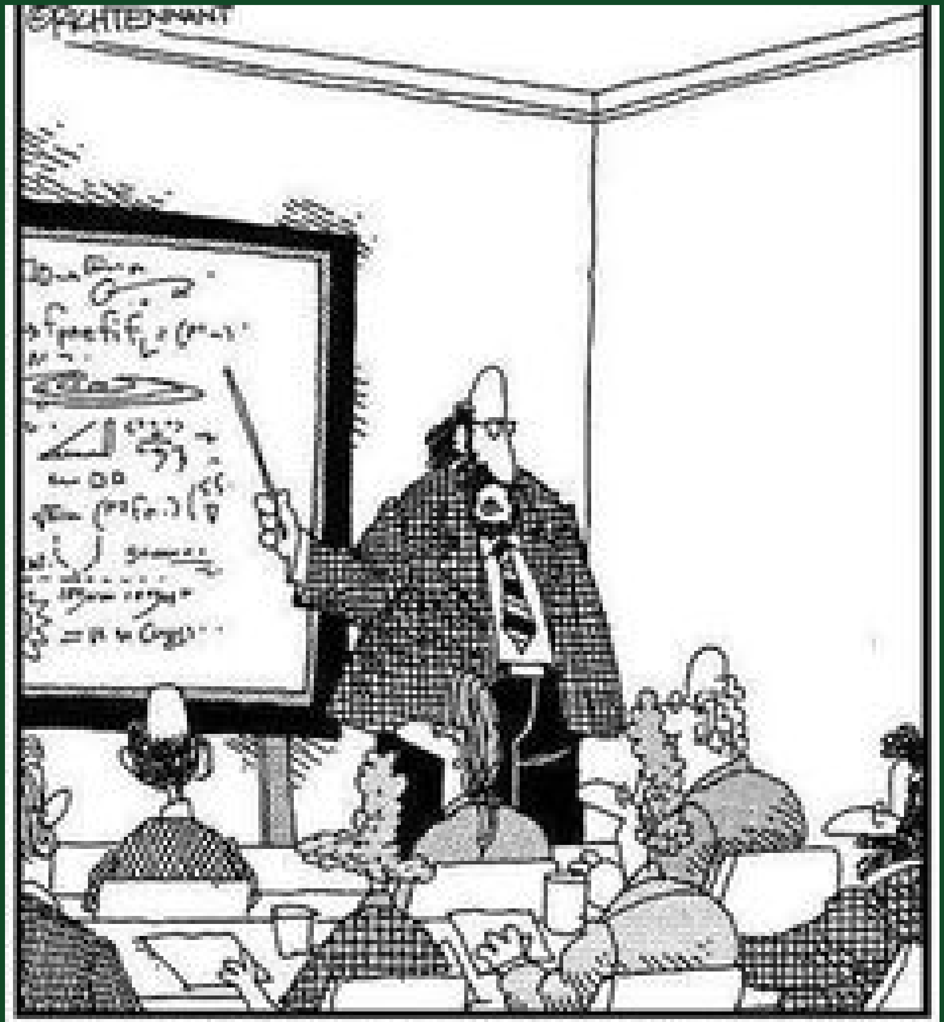


"And see this ring right here, Jimmy? . . . That's another time when the old fellow miraculously survived some big forest fire."



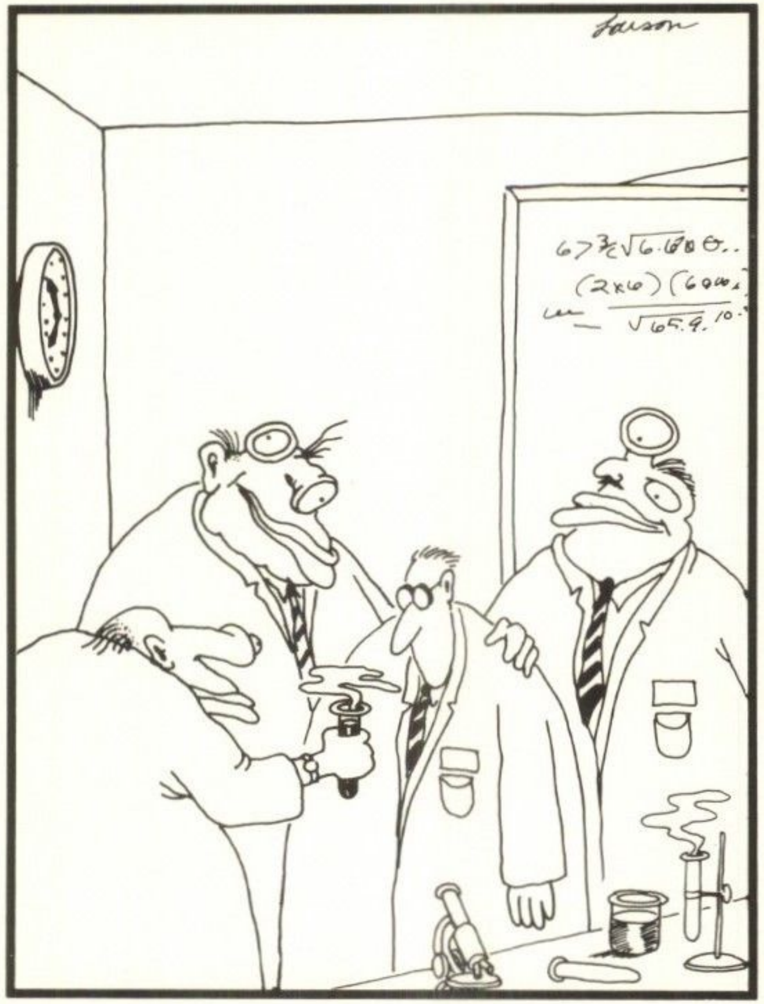
"It's time we face reality, my friends. ...
We're not exactly rocket scientists."

By: Gary Larson



"Along with 'Antimatter,' and 'Dark Matter,' we've recently discovered the existence of 'Doesn't Matter,' which appears to have no effect on the universe whatsoever."

By: Rich Tennant



Laboratory peer pressure

By: Gary Larson

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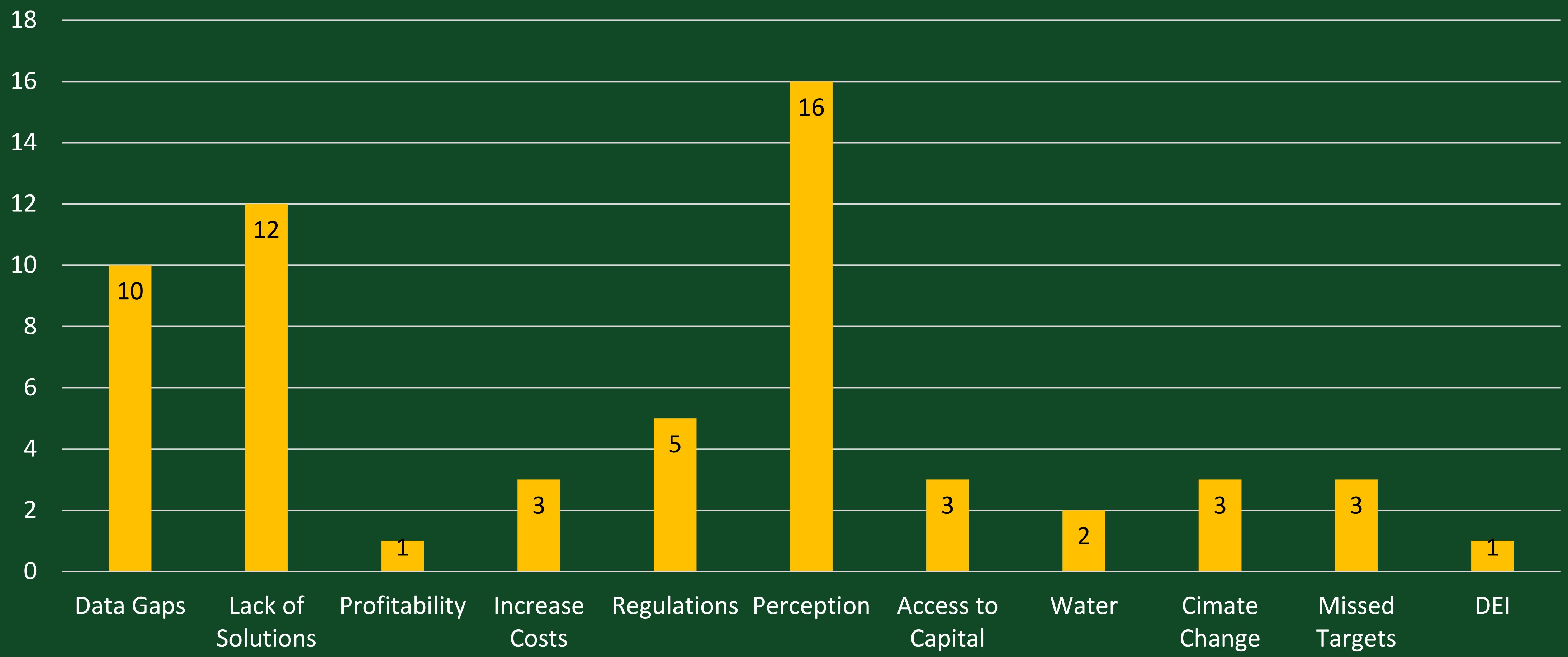
What is your companies biggest risk related to sustainability?



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Dr. Sara Place
Chief Sustainability Officer, Elanco Animal Health

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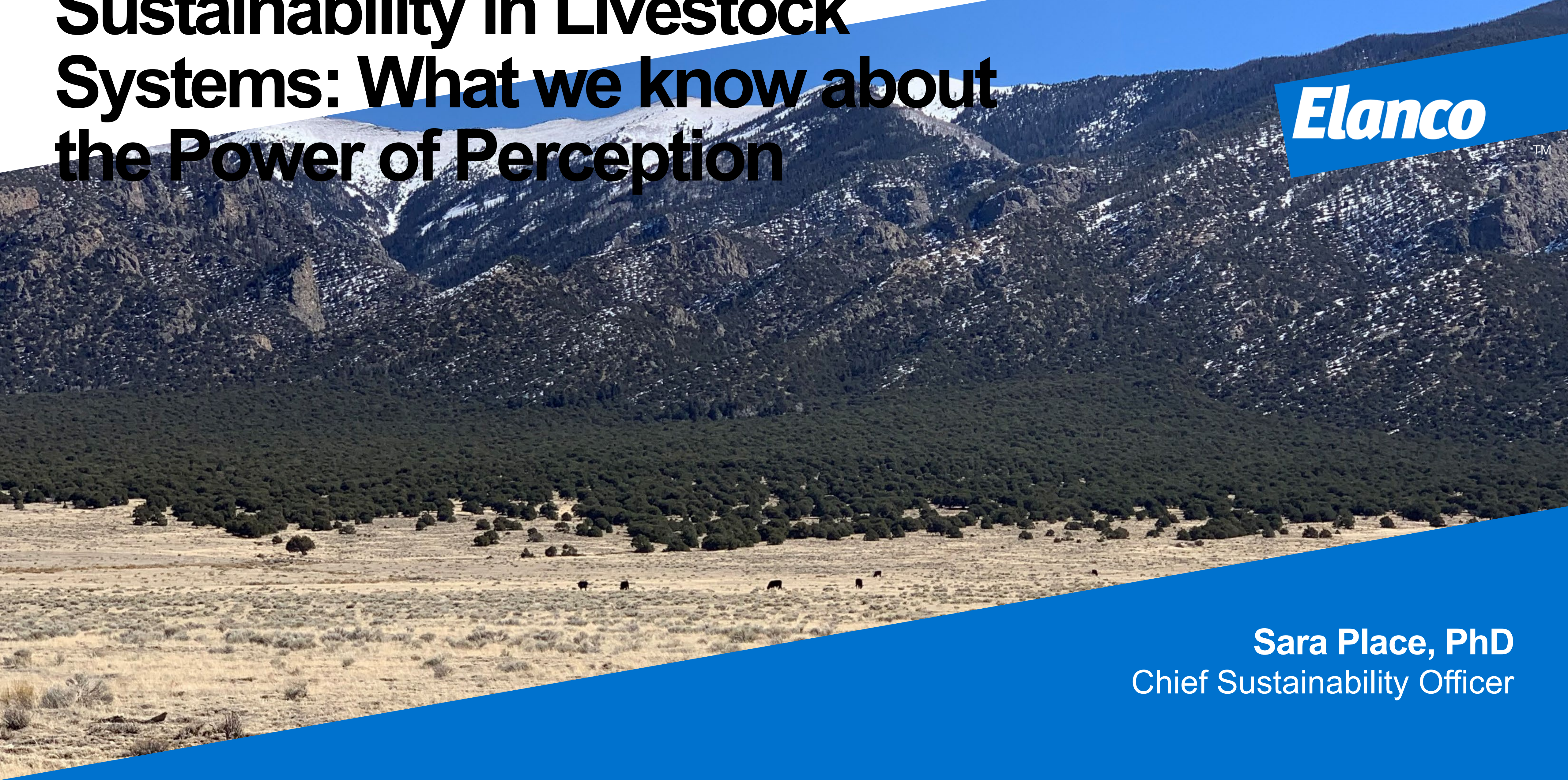
December 1, 2021

Sustainability in Livestock Systems: What we know about the Power of Perception



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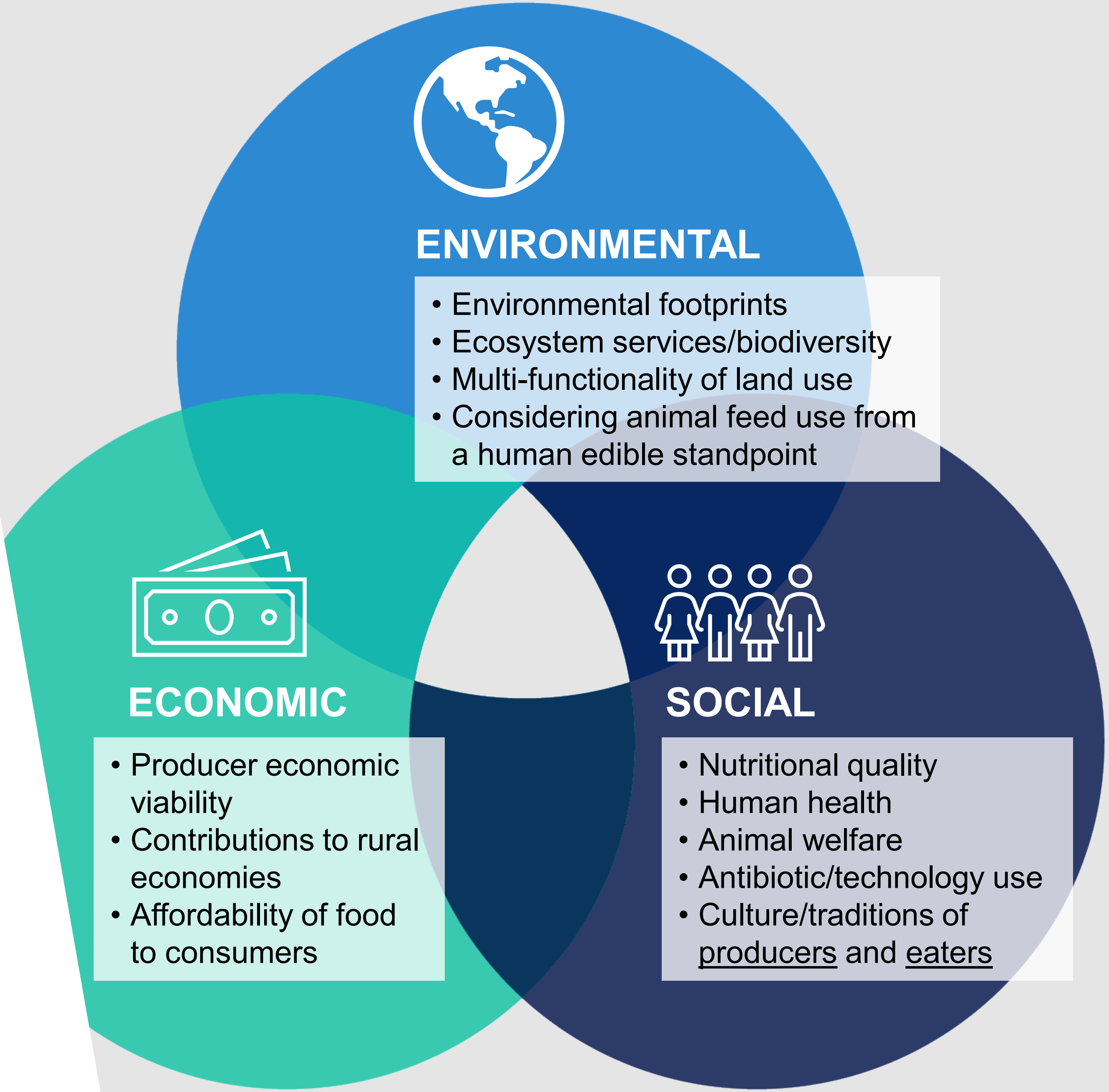
Sara Place, PhD
Chief Sustainability Officer

Sustainability is complex & full of value judgments, yet the issue that dominates today is climate change

Questions that society is asking:

- What should we be eating?
- How should food be grown/produced?
- Can beef/dairy be a part of a sustainable diet?

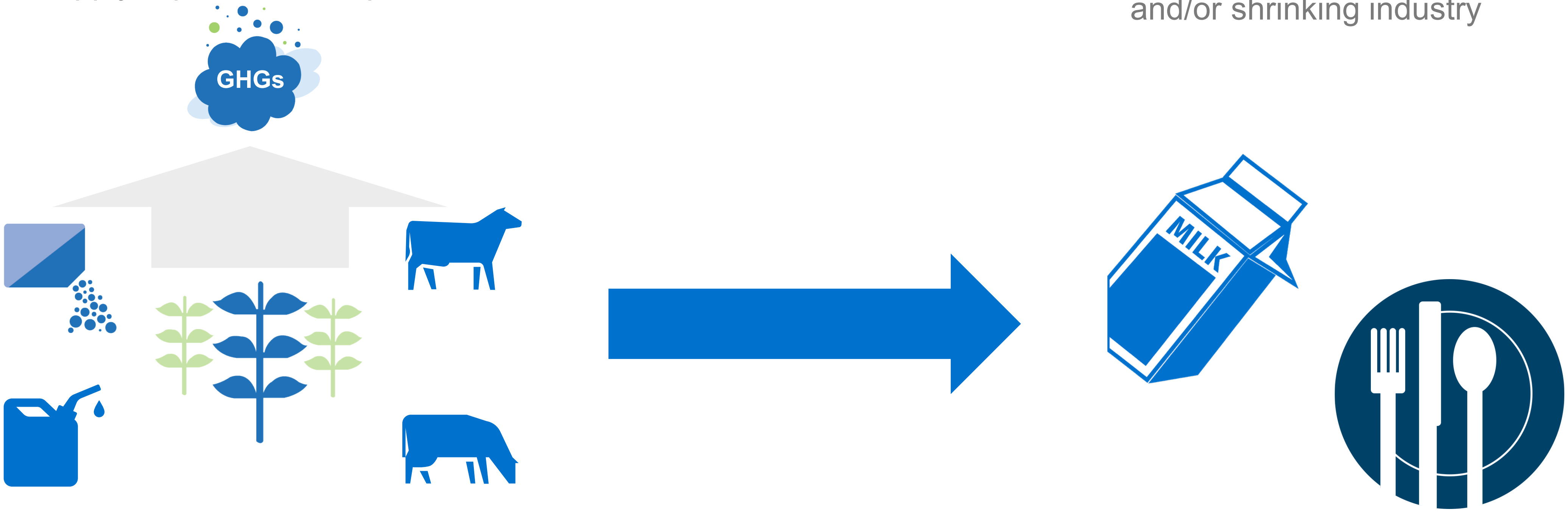


Simple reality: We can achieve progress on the supply side or the demand side

It's up to the cattle industry to determine if supply side alone can achieve societal expectations. We have knowledge gaps, economic barriers, and implementation challenges ahead

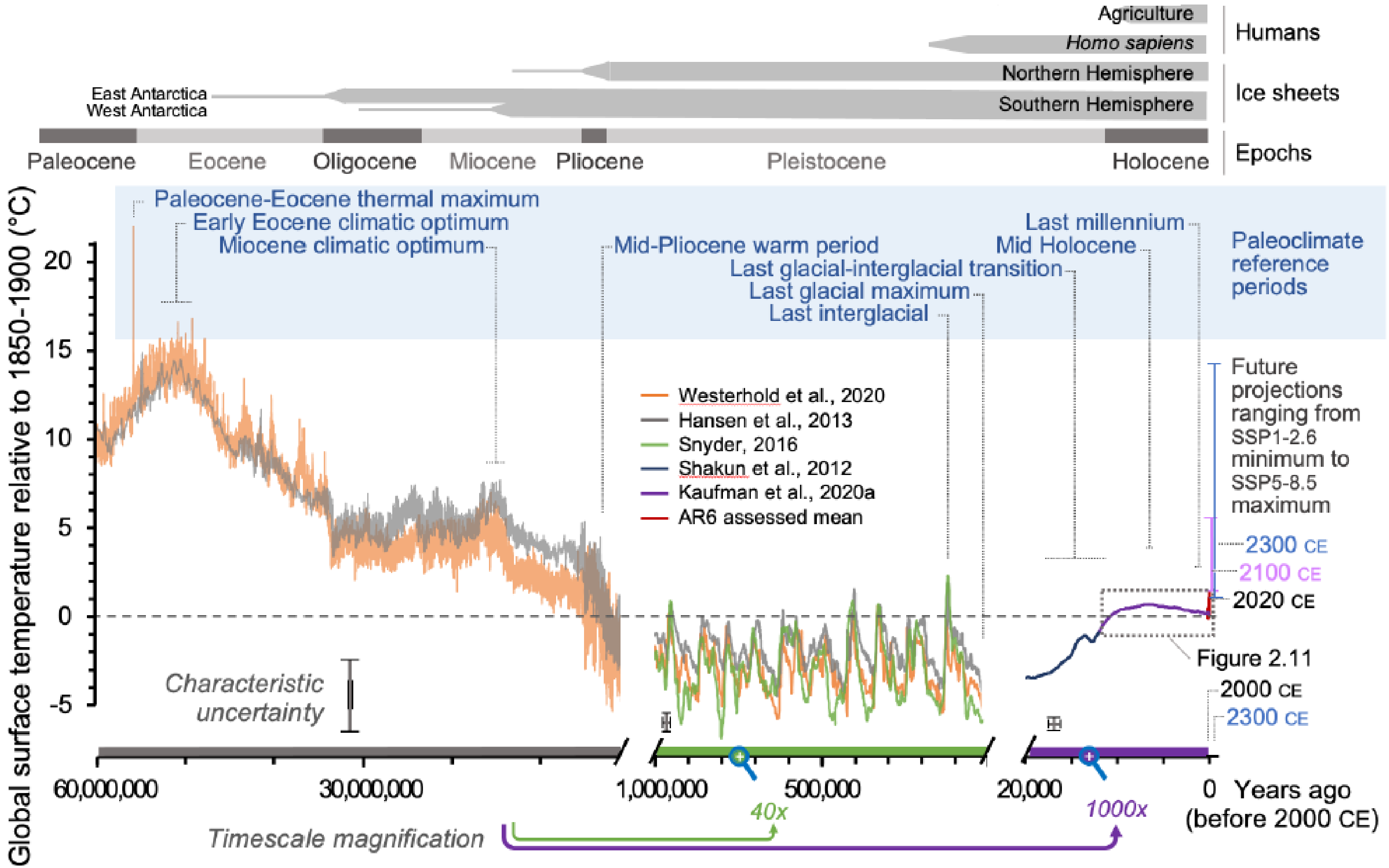
Supply & production improvements

Demand reduction: reduced growth and/or shrinking industry



Climate in Context

Earth's Recent Surface Temperature History



Cross-Chapter Box 2.1, Figure 1: Global mean surface temperature (GMST) over the past 60 million years relative to 1850-1900 shown on three time scales.

Gulev, S. K., P. W. Thorne, J. Ahn, F. J. Dentener, C. M. Domingues, S. Gerland, D. Gong, D. S. Kaufman, H. C. Nnamchi, J. Quaas, J. A. Rivera, S. Sathyendranath, S. L. Smith, B. Trewin, K. von Shuckmann, R. S. Vose, 2021, Changing State of the Climate System. In: 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. In Press.

Greenhouse effect keeps global average temperature at ~57 °F.

Without the greenhouse effect, global average temperature would be less than 0°F.

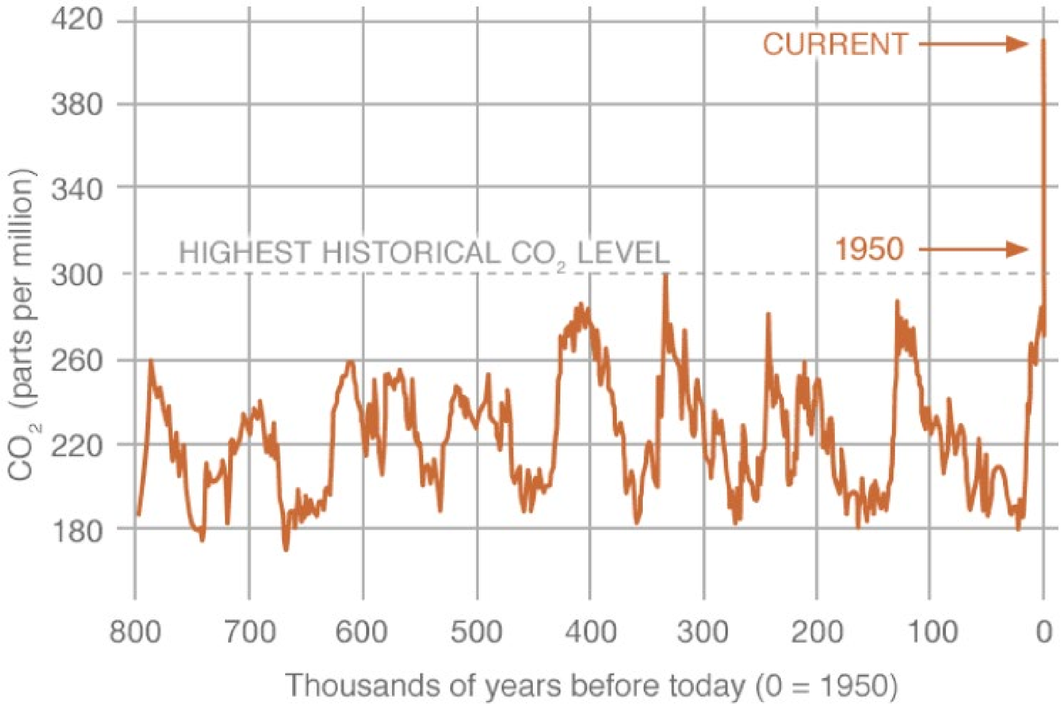
Available at: https://climate.nasa.gov/climate_resources/188/graphic-the-greenhouse-effect/

Carbon dioxide (CO_2) concentrations within the atmosphere have increased rapidly in the past few decades

"Over the past 171 years, **human activities have raised atmospheric CO2 concentrations by 48%** above pre-industrial levels found in 1850. This is **more than what had happened naturally over a 20,000 year period** (from the Last Glacial Maximum to 1850, from 185 ppm to 280 ppm)."

PROXY (INDIRECT) MEASUREMENTS

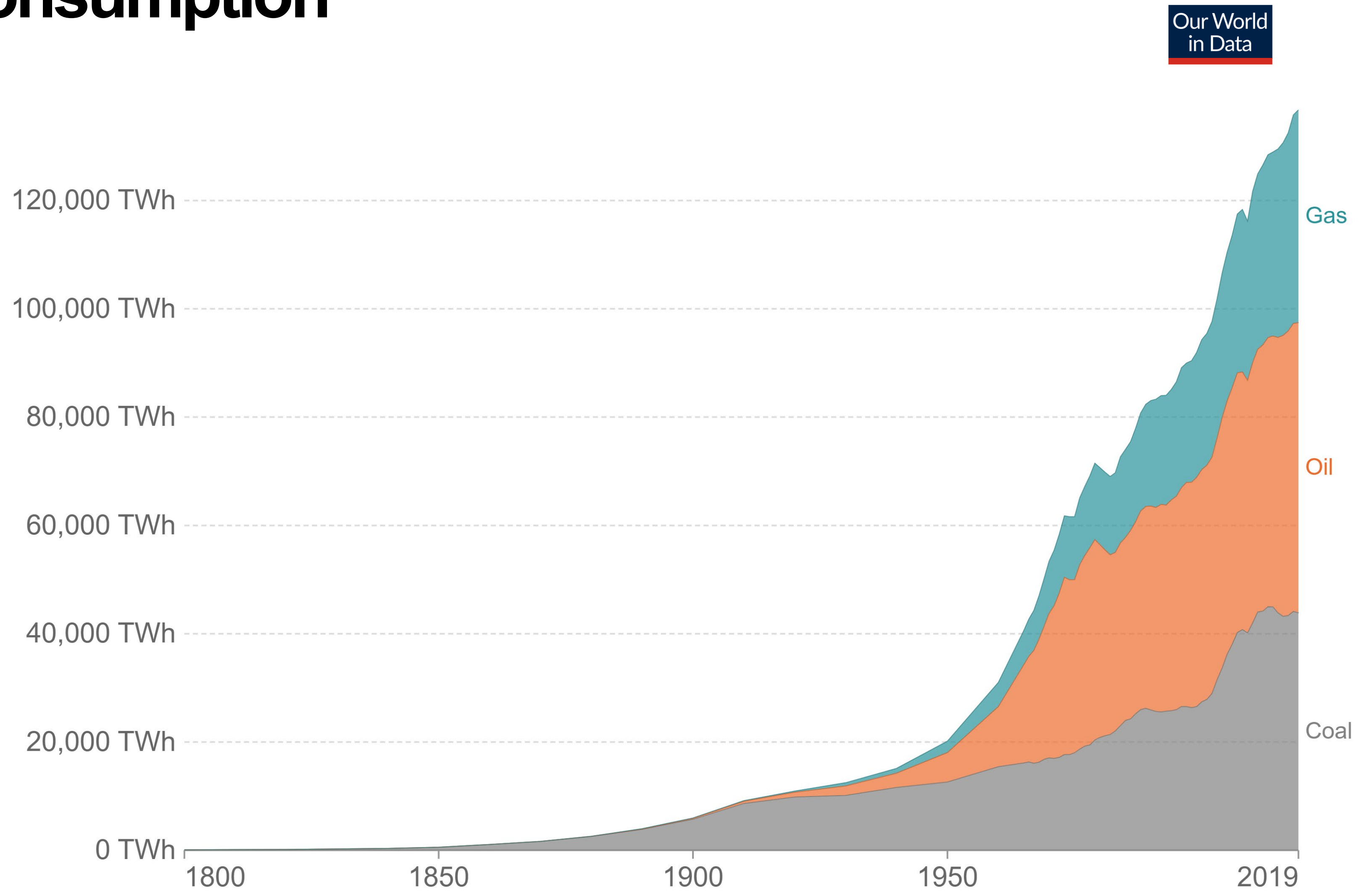
Data source: Reconstruction from ice cores.
Credit: NOAA



Available at: https://climate.nasa.gov/vital-signs/carbon-dioxide/

Global Fossil Fuel Consumption

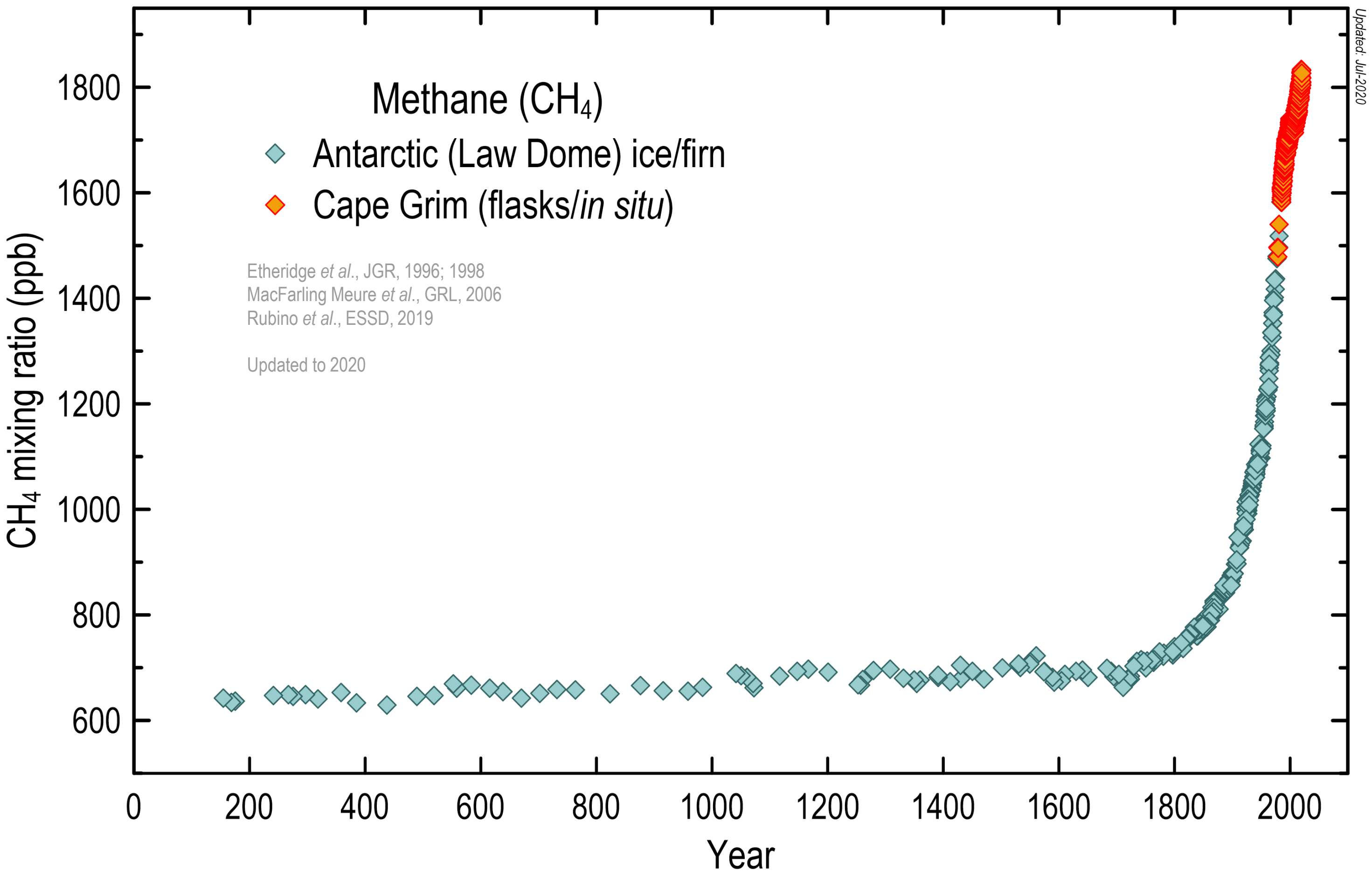
Global primary energy consumption by fossil fuel source, measured in terawatt-hours (TWh)



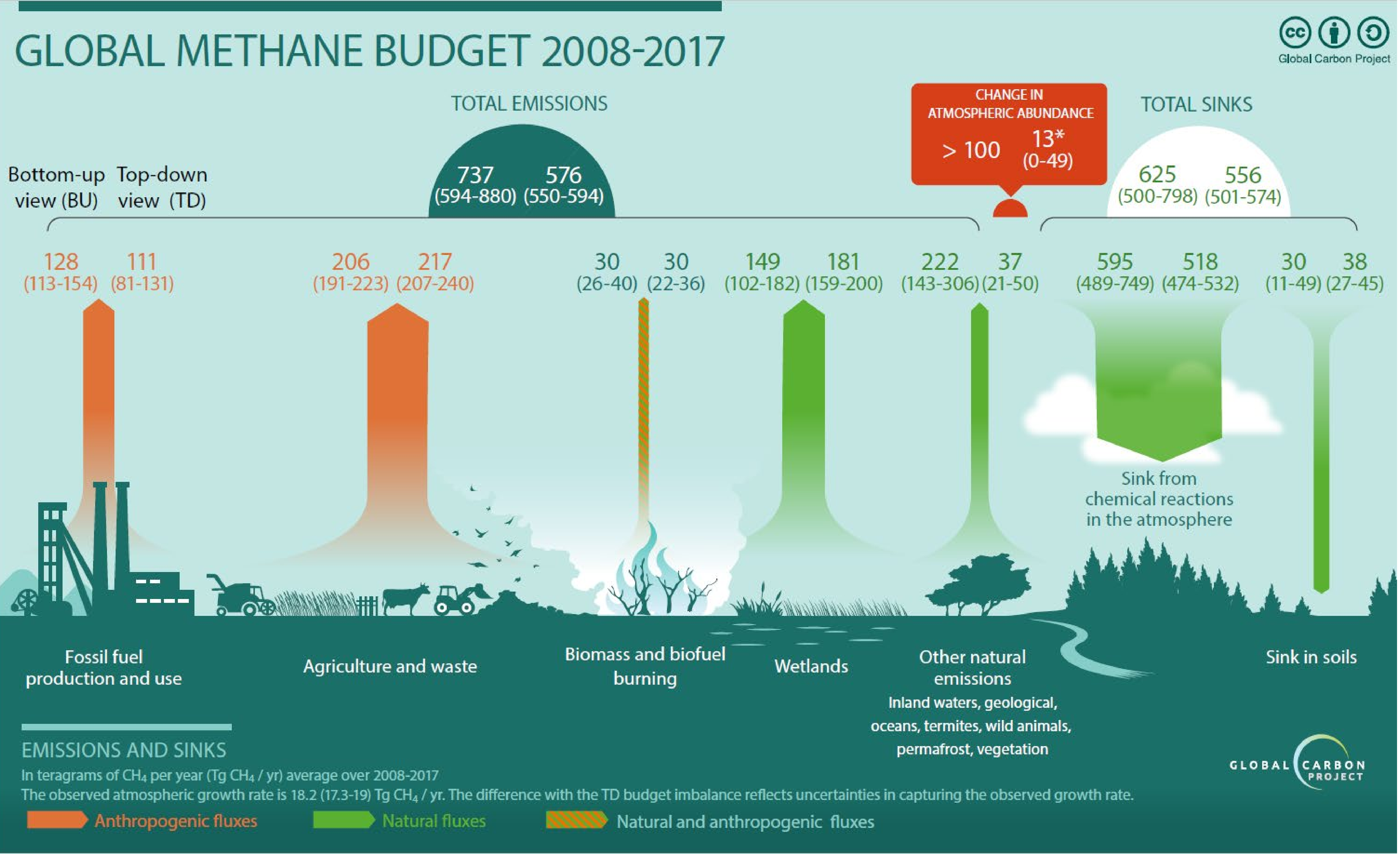
Source: Vaclav Smil (2017), Energy Transitions: Global and National Perspective & BP Statistical Review of World Energy
OurWorldInData.org/fossil-fuels/ • CCBY

Available at: https://ourworldindata.org/fossil-fuels

Methane (CH_4) is the second most important anthropogenic GHG and has also increased atmospheric concentrations since the Industrial Revolution (up 150% since 1750)



Available at: https://www.globalcarbonproject.org/methanebudget/20/presentation.htm


GLOBAL METHANE BUDGET 2008-2017
Global Carbon Project
TOTAL EMISSIONS
737 (594-880) 576 (550-594)
CHANGE IN ATMOSPHERIC ABUNDANCE
> 100 13* (0-49)
TOTAL SINKS
625 (500-798) 556 (501-574)
Bottom-up view (BU)
Top-down view (TD)
128 (113-154) 111 (81-131)
206 (191-223) 217 (207-240)
30 (26-40) 30 (22-36)
149 (102-182) 181 (159-200)
222 (143-306) 37 (21-50)
595 (489-749) 518 (474-532)
30 (11-49) 38 (27-45)
Sink from chemical reactions in the atmosphere
Fossil fuel production and use
Agriculture and waste
Biomass and biofuel burning
Wetlands
Other natural emissions
Inland waters, geological, oceans, termites, wild animals, permafrost, vegetation
Sink in soils
EMISSIONS AND SINKS
In teragrams of CH_4 per year (Tg CH_4 / yr) average over 2008-2017
The observed atmospheric growth rate is 18.2 (17.3-19) Tg CH_4 / yr. The difference with the TD budget imbalance reflects uncertainties in capturing the observed growth rate.
Anthropogenic fluxes
Natural fluxes
Natural and anthropogenic fluxes
GLOBAL CARBON PROJECT

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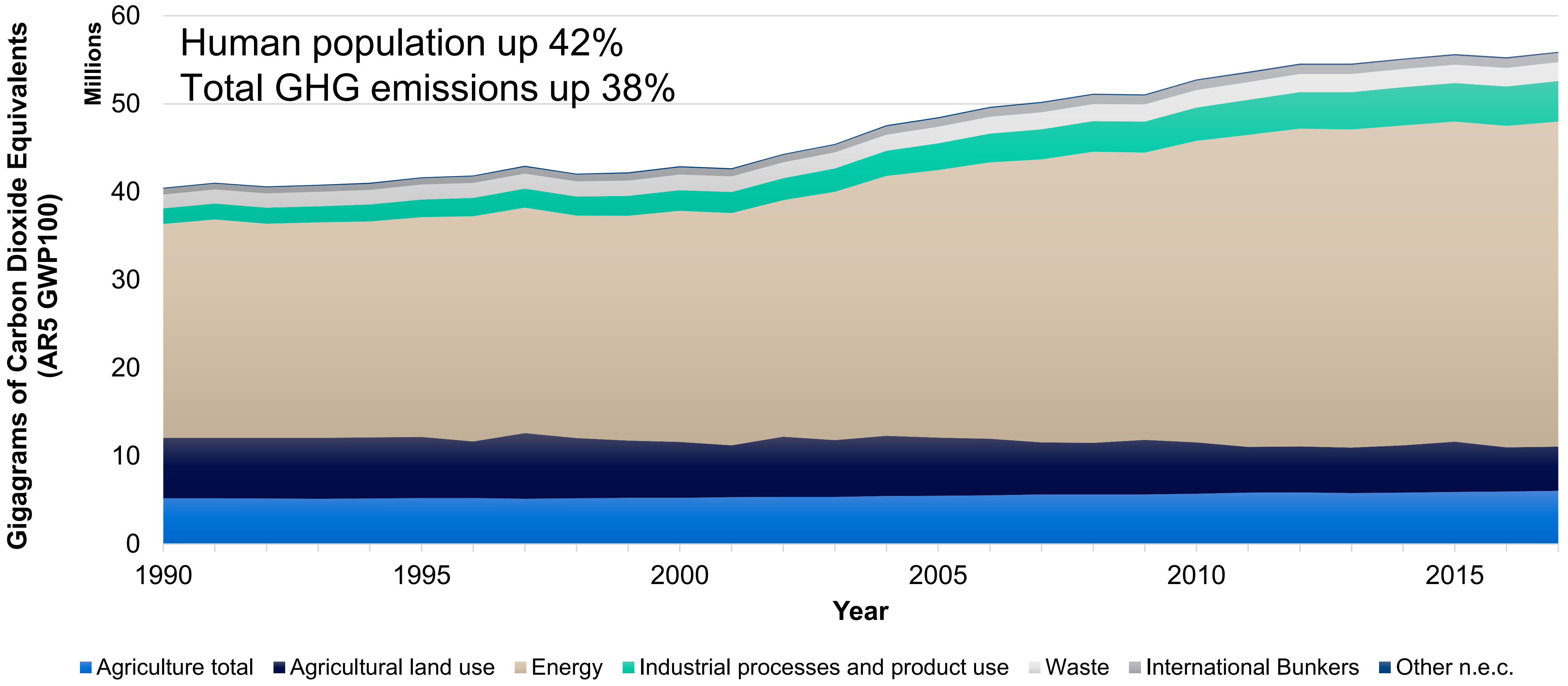
Greenhouse Gas Emissions in Context

Global Greenhouse Gas Emissions Trends, 1990 - 2017

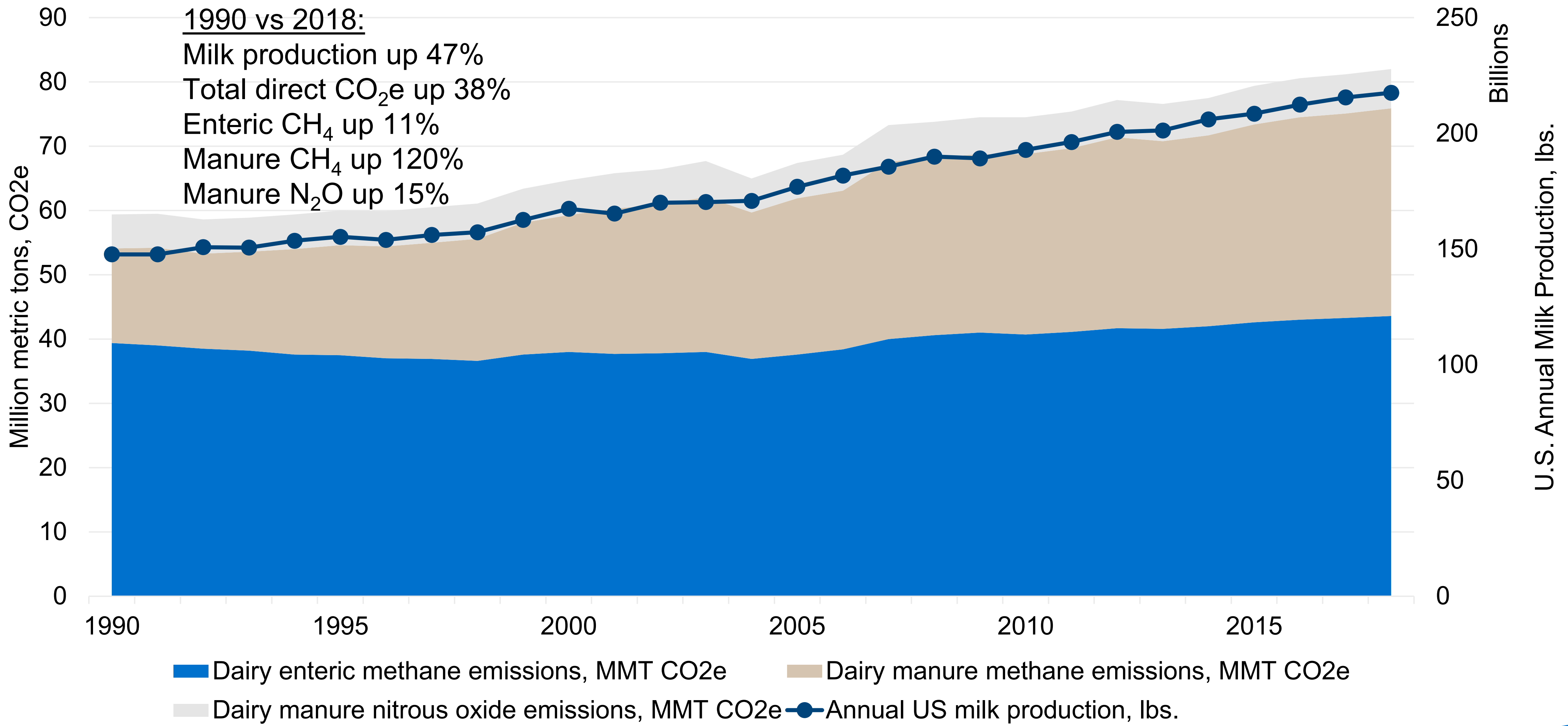


Source: UN FAOSTAT database; http://www.fao.org/faostat/en/#data

Data from U.S. EPA GHG Inventory

US Dairy Emissions

Direct US dairy GHG emissions in CO_2e and milk production



United States Department of Agriculture. National Agriculture Statistics Service. Available at: https://quickstats.nass.usda.gov/
US Environmental Protection Agency. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2018. 2020. available at: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2018

Key areas to impact on reducing GHG emissions from dairy cattle production

- Feed production
  - Reduce emissions, increase soil C
- Enteric methane emissions
  - Direct
  - Indirect
- Manure emissions
  - Renewable energy opportunities
- Reduce fossil energy use

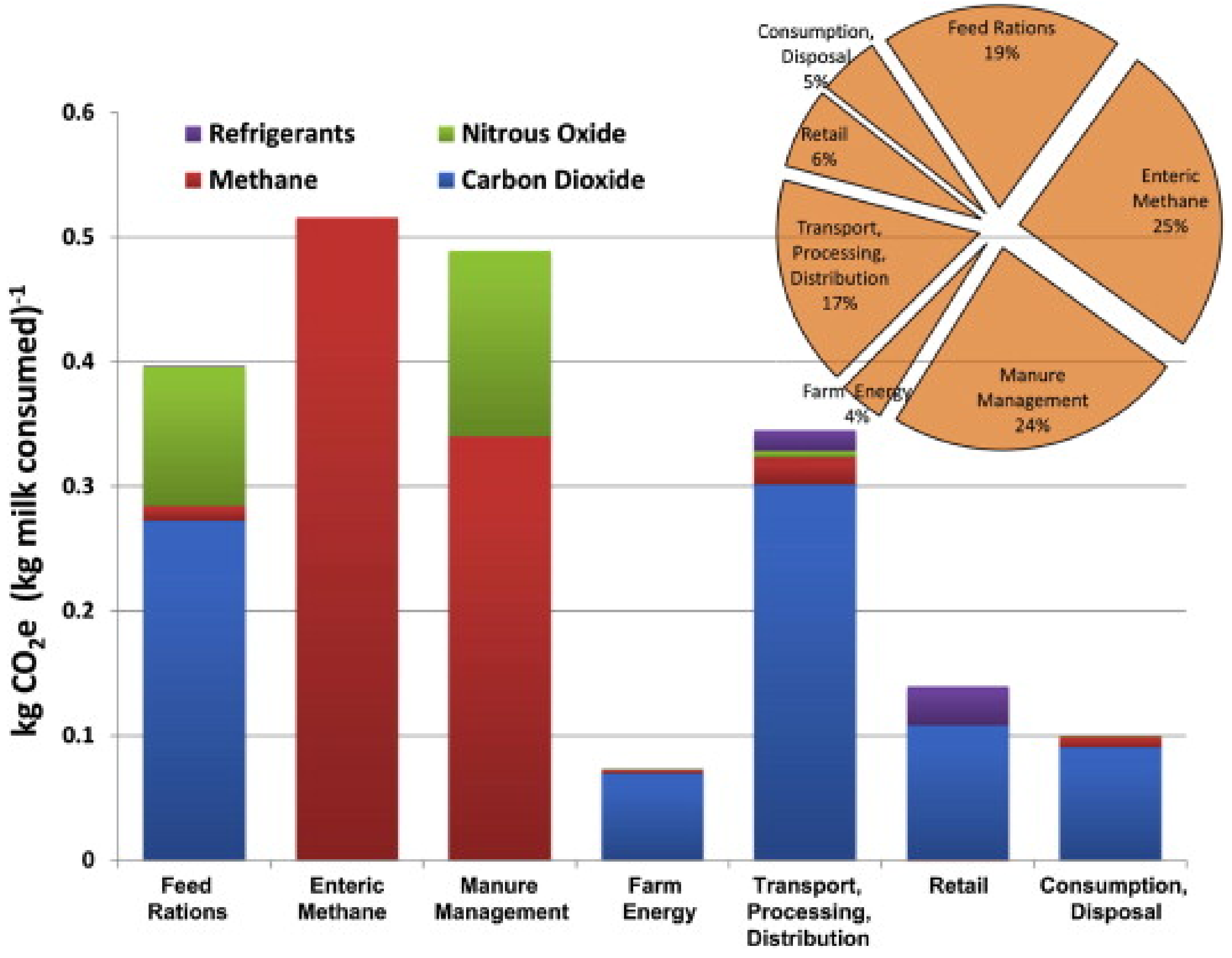


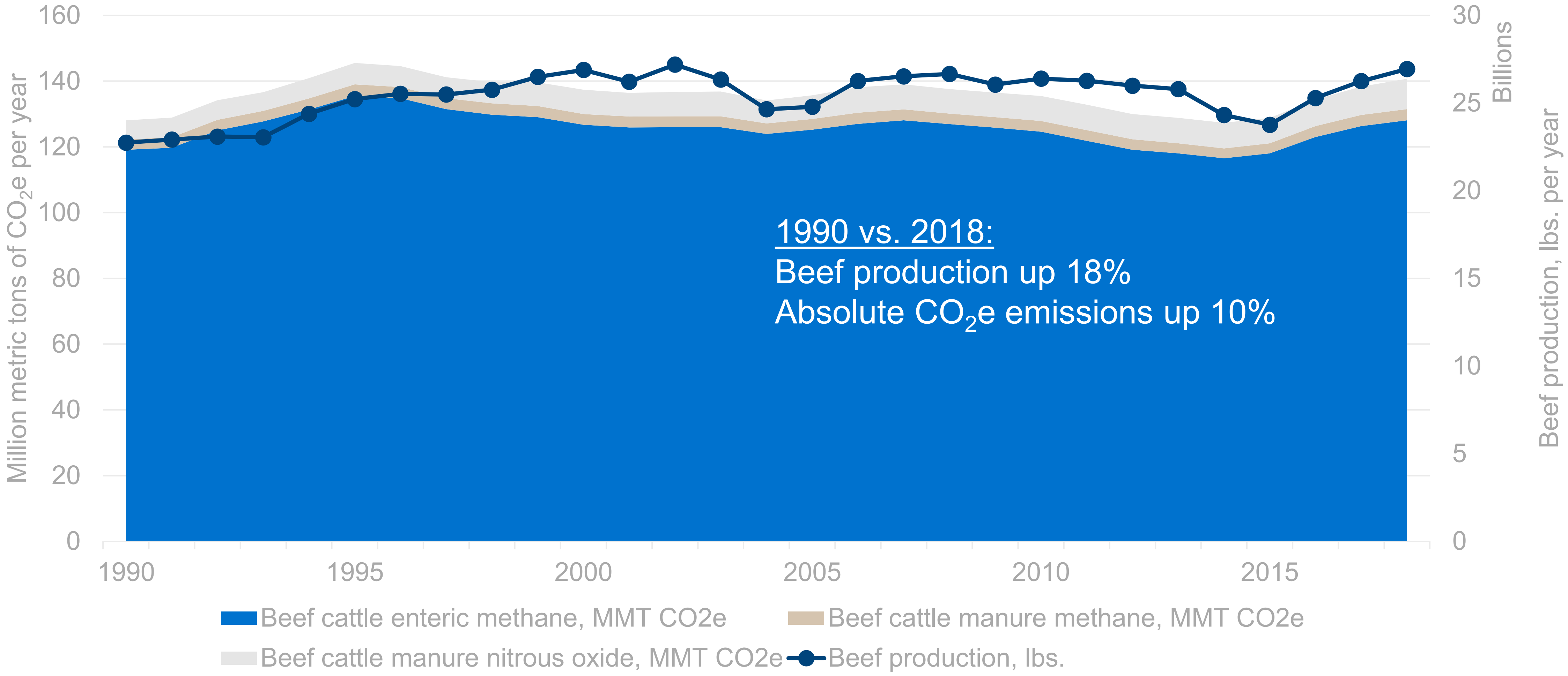
Fig. 6. Supply chain contribution to carbon footprint of 'generic' milk. Generic milk refers to regional-production-weighted (raw milk input) and purchase-volume-weighted (milk fat content) average milk consumed in the US during 2007. Note that fuels, fertilizer, and milling are included in the feed stage. In addition, there is a 12% product loss accounted in retail, and an additional 20% wasted product in the consumption phase.

Thoma et al., 2013. Greenhouse gas emissions from milk production and consumption in the United States: A cradle-to-grave life cycle assessment circa 2008. Int. Dairy J. 31(Suppl. 1): S3-S14.

Data from U.S. EPA GHG Inventory

US Beef Emissions

Direct US beef GHG emissions in CO_2e and beef production



United States Department of Agriculture. National Agriculture Statistics Service. Available at: https://quickstats.nass.usda.gov/
US Environmental Protection Agency. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2018. 2020. available at: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2018

The Climate Balance Sheet for US Beef Cattle Production

EMISSIONS SOURCES (% OF TOTAL[1]):

Enteric methane emissions (56%)

- Cow-calf production = 77% of enteric methane emissions
- Opportunities: improved production efficiency, reduced mortality, increased digestibility of feedstuffs, new innovations to inhibit methane

Feed/soil emissions (24%)

- Mostly soil nitrous oxide
- Opportunities: improvements in crop yields, optimized fertilizer use, integration of cattle & crops

Fossil fuel & input emissions (17%)

- Equipment, fertilizer, electricity, lime
- Opportunities: energy efficiency, optimized fertilizer use

Manure emissions (3%)

- Manure nitrous oxide & methane
- Opportunities: Manure management strategies and innovations customized to operations (e.g., composting, anaerobic digestion where relevant)

[1]Rotz, CA, Asem-Hiablie, S, Place, S, Thoma, G. Environmental Footprints of Beef Cattle Production in the United States. Agricultural Systems [Internet]. 2019 Feb [cited 2020 Aug 13]. 169:1-13. https://www.sciencedirect.com/science/article/pii/S0308521X18305675

CARBON SEQUESTRATION:

Pasture and rangelands

- Opportunities: Maintain soil C stores, increase soil where possible via management & re-establishment on degraded/highly erodible croplands

Row crops fed to cattle

- Opportunities: increase no-till/reduced tillage, cover crops, integration with cattle & other livestock

REDUCE EMISSIONS

+

MAINTAIN & ENHANCE SINKS

=

NET ZERO CLIMATE IMPACT

US Environmental Protection Agency. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2018. 2020. available at: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2018

US Cattle Emissions

- Both beef and dairy are dominated by methane (enteric + manure)
- Critically important to understand the implications of different climate metrics & how different metrics relate to climate goals

Accounting for Short-lived GHG Emissions Separately to Better Link Emissions to Warming

OXFORD MARTIN SCHOOL

UNIVERSITY OF OXFORD

Net zero for agriculture

Oxford Martin Programme on Climate Pollutants

August 2019

To design effective policies to stop global warming, we need to know the impact of different measures on temperature. This has long been a challenge for action involving short-lived climate pollutants such as methane. CO_2-warming-equivalent (CO_2-we) emissions provide a simple but accurate way of assessing the glob temperature outcomes of different mitigation options, avoiding well-known problems arising from the use of conventional CO_2-equivalent (CO_2-e) emissions.

Article | Open Access | Published: 04 September 2019

Improved calculation of warming-equivalent emissions for short-lived climate pollutants

Michelle Cain, John Lynch, Myles R. Allen, Jan S. Fuglestvedt, David J. Frame & Adrian H Macey

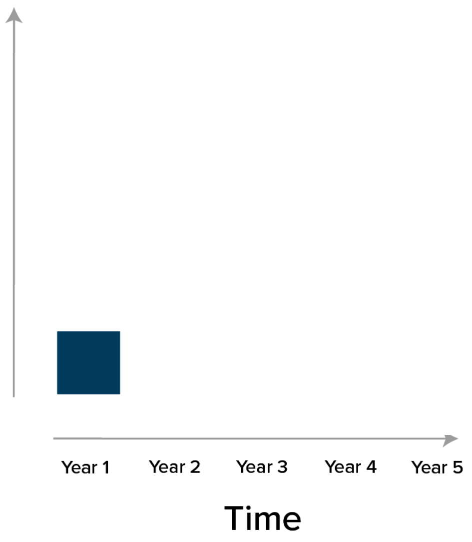
npj Climate and Atmospheric Science **2**, Article number: 29 (2019) | Cite this article

■ = Pulse of CO_2

Stock Gas

Carbon dioxide (CO_2)

Atmospheric Concentration



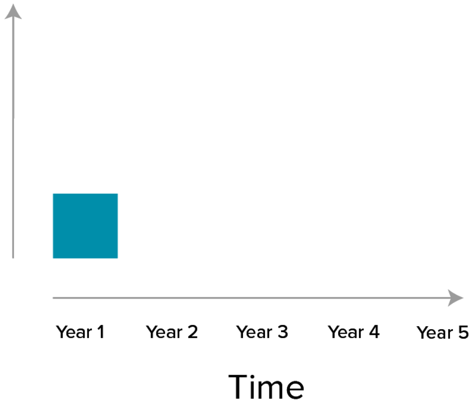
Stock gases will accumulate over time, because they stay in the environment.

■ = Pulse of CH_4

Flow Gas

Methane (CH_4)

Atmospheric Concentration



Flow gases will stay stagnant, as they are destroyed at the same rate of emission.

<u>If**</u>** emissions and sinks are in balance

Based on research by Myles R. Allen, Keith P. Shine, Jan S. Fuglestvedt, Richard J. Millar, Michelle Cain, David J. Frame & Adrian H. Macey.
Read more here: https://rdcu.be/b1t7S

UCDAVIS CLEAR Center

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The "So-what" of New Climate Metrics for Short-lived Gases

Better reflects reality of how emissions impact temperature

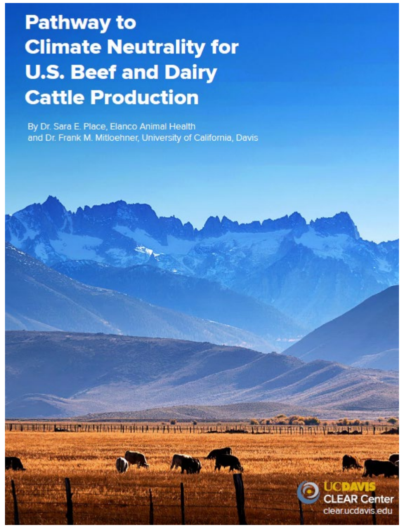
- This is what we actually care about

Highlights that methane emissions do not have to be zero to reach "climate neutrality"

- Climate neutrality defined here as not contributing to additional warming or achieving net zero warming

Important for beef/cattle as methane is the largest GHG in profile

- But, it's not the only GHG associated with cattle production!



If the Goal is Climate Neutrality for US Cattle,
What Could that Look Like?

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Assumptions in Scenario to Reach Climate Neutrality for Beef

Item	2020	2050	% change from 2020
Total non-dairy cattle, Jan. 1	**79,766,700**	**79,549,600**	**-0.3%**
Beef production, billion lbs.	**27.1**	**31.2**	**+15%**
Beef cattle enteric CH_4, Tg CO_2e[1]	175.5	136.0	-23%
Feedlot cattle enteric CH_4/d, g/hd	127	96	-24%
Beef cow enteric CH_4/d, g/d	262	204	-22%
Indirect GHG emissions, Tg CO_2e[1]	101.4	72.3	-28%
Carbon footprint, kg CO_2e/kg beef carcass[1,2]	23.72	15.70	-34%
Total GHG emissions, Tg CO_2e[1]	291.3	222.4	-24%

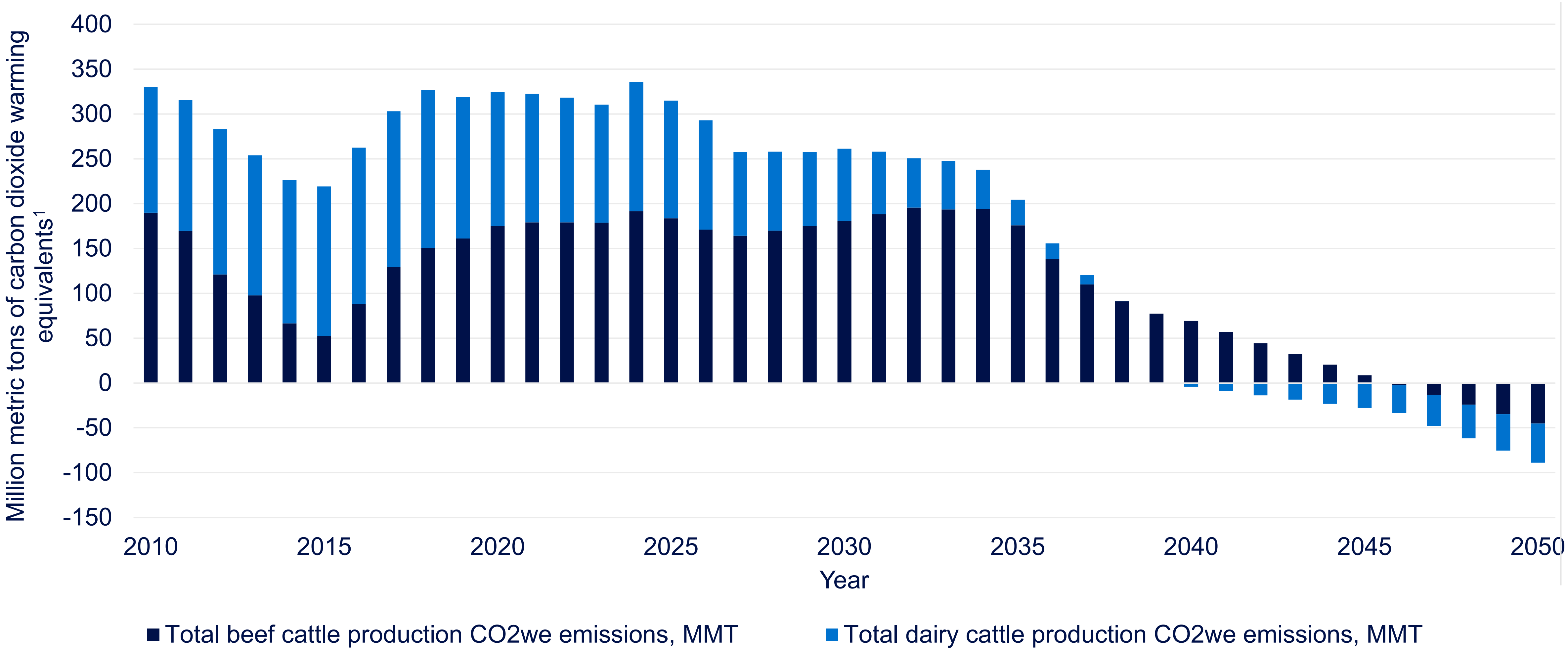
[1]Carbon dioxide equivalents (CO_2e) using GWP100 values of 34 and 298 for methane and nitrous oxide, respectively
[2]The carbon footprint here does not allocate emissions to or from dairy cattle, but rather only accounts for enteric and manure emissions directly attributed to non-dairy cattle within the U.S. EPA GHG inventory. For comparison, Rotz et al. (2019) found a U.S.-wide carbon footprint for beef cattle production of 21.3 kg CO2e/kg carcass weight using GWP100 values of 28 and 265 for CH4 and N2O, respectively. The 2020 footprint reported here would be 21.04 kg CO2e/kg carcass weight using those GWP100 values

Assumptions in Scenario to Reach Climate Neutrality for Dairy

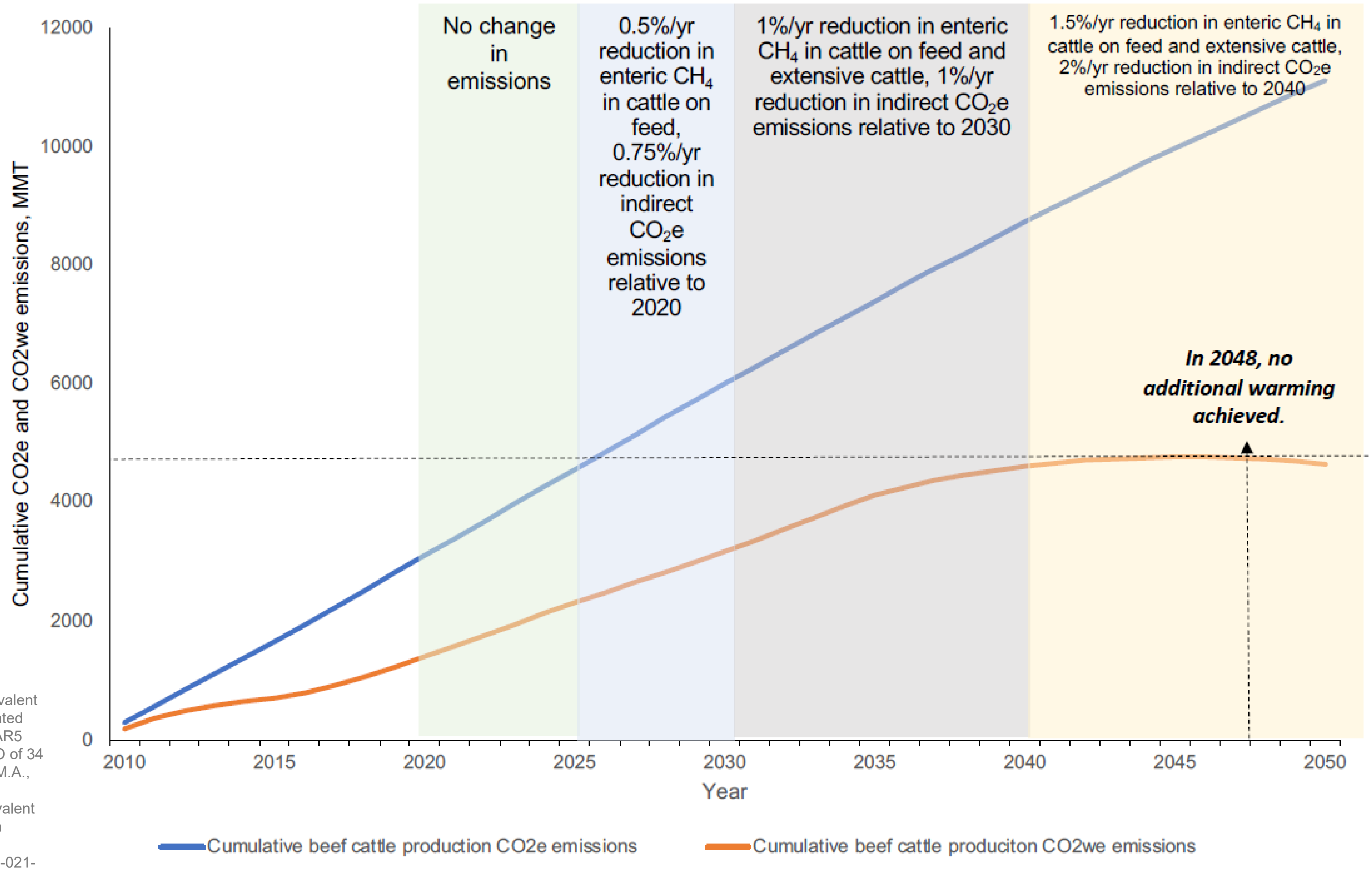
Item	2020	2050	% change from 2020
Total dairy cows, Jan. 1	**9,342,600**	**9,440,000**	**+1%**
Milk production, billion lbs.	**223.2**	**332.3**	**+49%**
Dairy cattle enteric CH_4, Tg CO_2e[1]	58.8	48.3	-18%
Manure CH4 emissions, Tg CO2e	43.4	30.0	-31%
Dairy cow enteric CH_4/d, g/d	404	311	-23%
Indirect GHG emissions, Tg CO_2e[1]	23.6	16.9	-28%
Carbon footprint, kg CO_2e/kg milk[1,2]	1.30	0.67	-48%
Total GHG emissions, Tg CO_2e[1]	131.7	101.2	-23%

[1]Carbon dioxide equivalent (CO2e) emissions are calculated using the 100-year global warming potentials of 34 and 298 for methane (CH4) and nitrous oxide (N2O), respectively
[2]The cradle-to-farm gate estimated here does not allocate any enteric and manure emissions from dairy cattle in the EPA GHG inventory to beef production. For comparison, a recent footprint analysis from Capper and Cady, 2020 estimated a dairy cattle footprint of 1.7 kg CO2e/kg milk using GWP100 values of 34 and 298 for CH4 and N2O, respectively. Thoma et al. (2013) reported a cradle-to-farm gate U.S. dairy average of 1.23 kg CO2e/kg fat-and-protein corrected milk (FPCM) using the GWP100 values of 25 and 298 for CH4 and N2O, respectively. Rotz et al. (2021) reported a U.S. dairy footprint of 1.01 kg CO2e/kg FPCM using the GWP100 values of 28 and 265 for CH4 and N2O, respectively.

Climate Neutrality for US Beef & Dairy Cattle Production by 2044

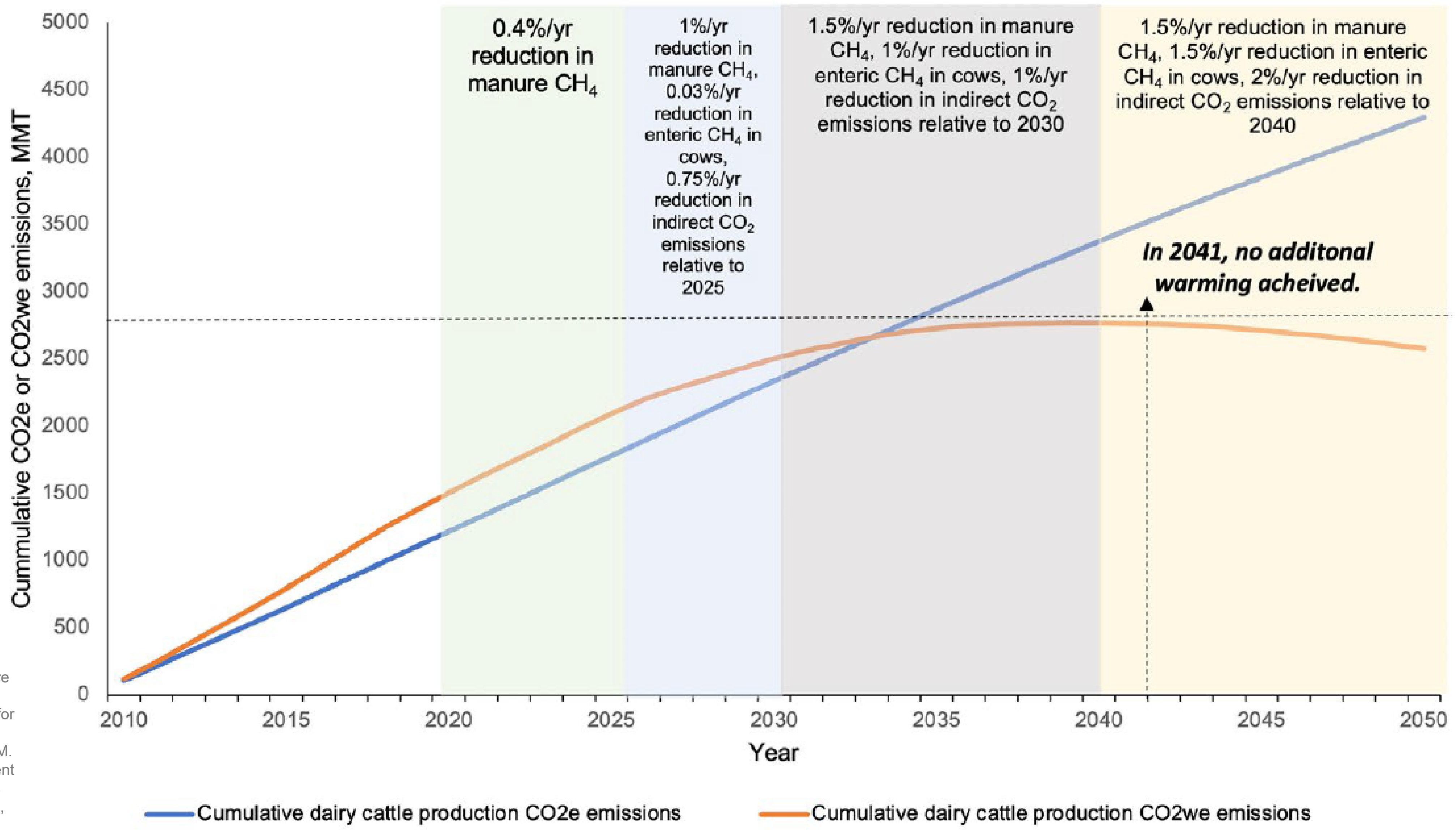


[1]Carbon dioxide warming equivalent (CO_2we) emissions are calculated using 20-year time horizon & AR5 GWP100 values for CH_4 & N_2O of 34 and 298, respectively. Smith, M.A., Cain, M. & Allen, M.R. Further improvement of warming-equivalent emissions calculation. npj Clim Atmos Sci 4, 19 (2021). https://doi.org/10.1038/s41612-021-00169-8



[1]Carbon dioxide warming equivalent (CO_2we) emissions are calculated using 20-year time horizon & AR5 GWP100 values for CH_4 & N_2O of 34 and 298, respectively. Smith, M.A., Cain, M. & Allen, M.R. Further improvement of warming-equivalent emissions calculation. npj Clim Atmos Sci 4, 19 (2021). https://doi.org/10.1038/s41612-021-00169-8

Figure 6. *Cumulative carbon dioxide equivalent (CO_2e) or carbon dioxide warming equivalent (CO_2we) for US beef cattle production from 2010 to 2050 for the case study scenario. Assumed changes in emissions by time period are indicated on the graph. The point at which annual CO_2we emissions do not add to further warming is indicated on the graph.*



[1]Carbon dioxide warming equivalent (CO_2we) emissions are calculated using 20-year time horizon & AR5 GWP100 values for CH_4 & N_2O of 34 and 298, respectively. Smith, M.A., Cain, M. & Allen, M.R. Further improvement of warming-equivalent emissions calculation. npj Clim Atmos Sci 4, 19 (2021). https://doi.org/10.1038/s41612-021-00169-8

Figure 7. *Cumulative carbon dioxide equivalent (CO_2e) or carbon dioxide warming equivalent (CO_2we) for U.S. dairy cattle production from 2010 to 2050 for the case study scenario. Assumed changes in emissions by time period are indicated on the graph. The point at which annual CO_2we emissions do not add to further warming is indicated on the graph.*

What Would Be Needed To Reach Climate Neutrality While Maintaining Herd and Production Growth

Need to reduce emissions per head, not just per lb. of beef & milk

Enteric methane is a major "lever" to pull for beef:

- Genetics (feed intake, methane directly)
- Feed additives, feeding strategies
  - Challenge how to deliver to grazing cattle where ~82% of the methane emissions come from?
- Other innovations (e.g., vaccine?)

High penetration of US cattle enteric mitigation

$556 million value in dairy & fed cattle, $973 additional value in extensive cattle @ 70% market share & $40/t

	Fed beef cattle	Extensive beef cattle	Dairy cows	Dairy heifers	Total
Total enteric CH_4, MMT CO_2e[1]	17.0	112.1	34.5	8.8	172.3
Market share	70%	70%	70%	70%	
% reduction in enteric CH_4 per head	34%	31%	33%	31%	**-38 MMT**
Total value @**$40**/t CO_2e, USD	$161 million	$973 million	$319 million	$76 million	**$1.53 billion**

Fed beef cattle & extensive beef cattle: $0.06/lb. of beef carcass weight[2]

Dairy cows & dairy heifers: $0.26/cwt milk[2]

[1]Using GWP100 value for methane of 25, source: US EPA GHG Inventory for year 2019. Available at: https://www.epa.gov/sites/default/files/2021-04/documents/us-ghg-inventory-2021-annexes.pdf

[2] Using 2019 beef & milk production as base production from USDA-NASS Quick Stats database

What Would Be Needed To Reach Climate Neutrality While Maintaining Herd and Production Growth

Unlikely reducing enteric methane will get cattle production to climate neutrality alone, so need other reductions and/or increase C sinks

Other reduction examples:

- Reducing feed emissions (e.g., soil N_2O emissions)
- Reducing energy/fuel emissions

Carbon sequestration

- Potential to increase is likely highly dependent upon climate & land's prior use
- **Consideration: if carbon sold as an offset to buyers outside supply chain, can beef or dairy claim as well??**

Bottom Line

Climate neutrality for beef & dairy cattle production in the USA is likely possible and technically feasible

- But, it requires new innovations

We cannot lose focus of other aspects of sustainability

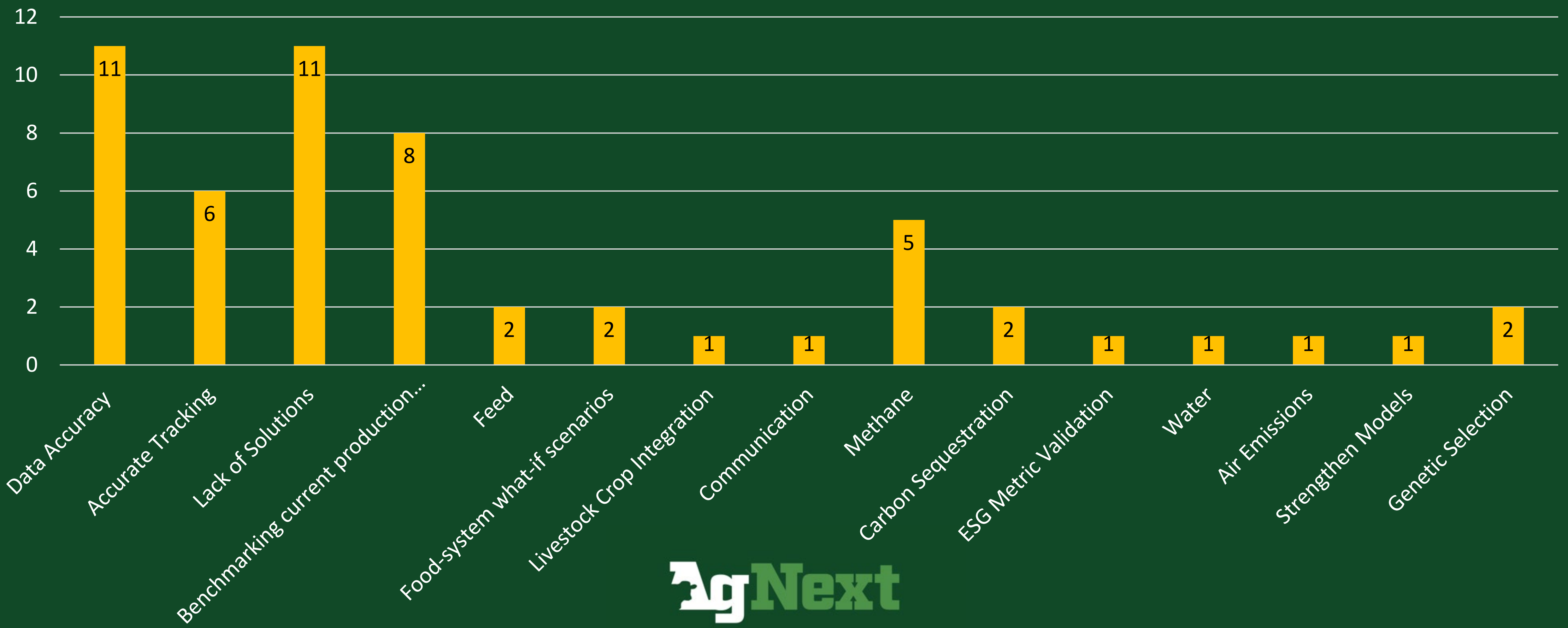
- First and foremost, need **economic viability**
- Cattle production is critical source of nutrition & ruminant benefits to sustainability are substantial (optimum land use, upcycling, wildfire suppression, etc.)

Societal perceptions are driving conversation & expectations are high

- Future pathways to tangibly achieve action are needed
- Gaps to fill in knowledge, implementation, economic feasibility, and people!

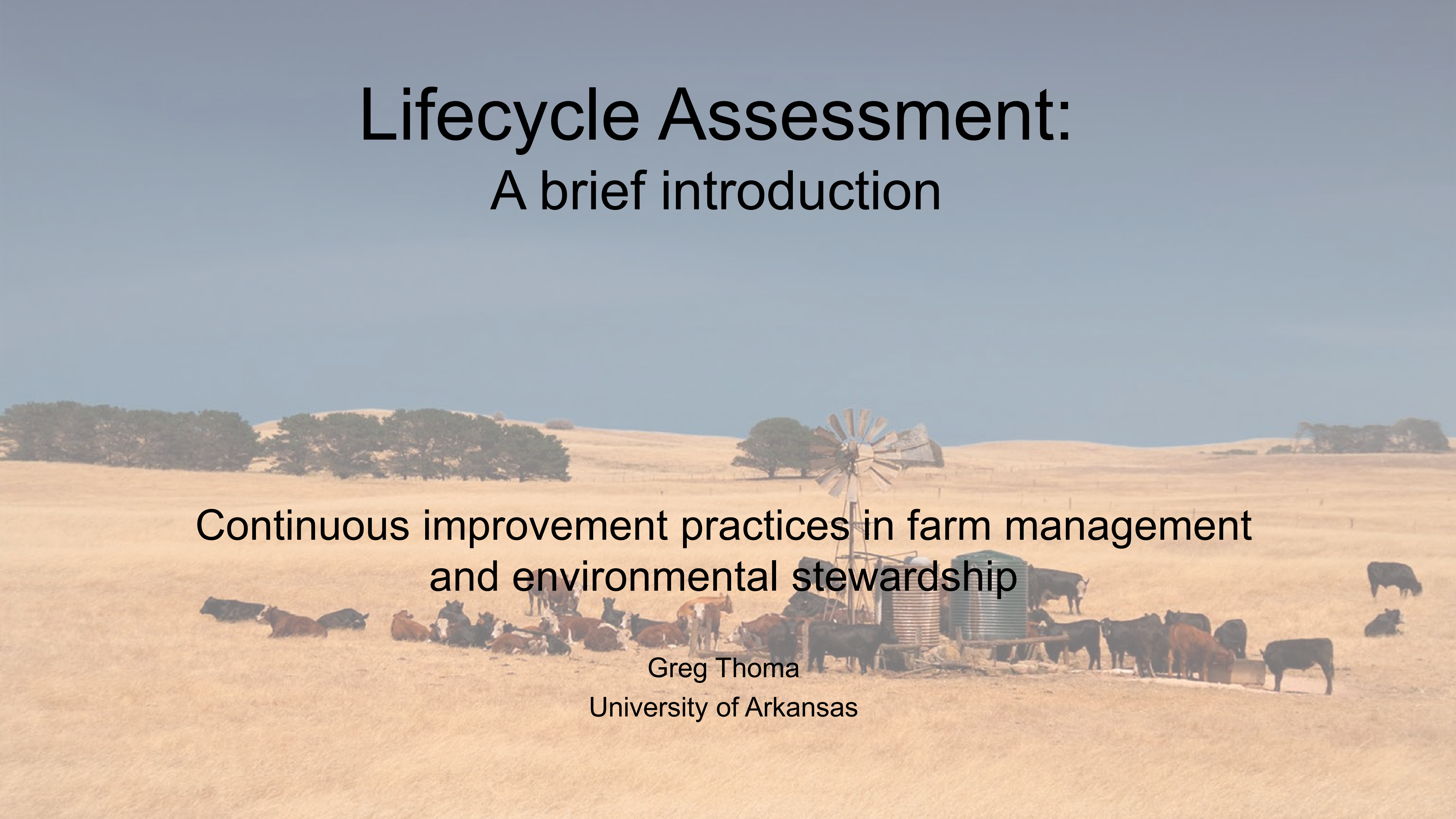
Thank You

What do you think the research gaps are in sustainability?



AgNext
COLORADO STATE UNIVERSITY
SUSTAINABLE SOLUTIONS
FOR ANIMAL AGRICULTURE

Panel: Innovative Solutions & Research Gaps



Lifecycle Assessment:

A brief introduction

Continuous improvement practices in farm management and environmental stewardship

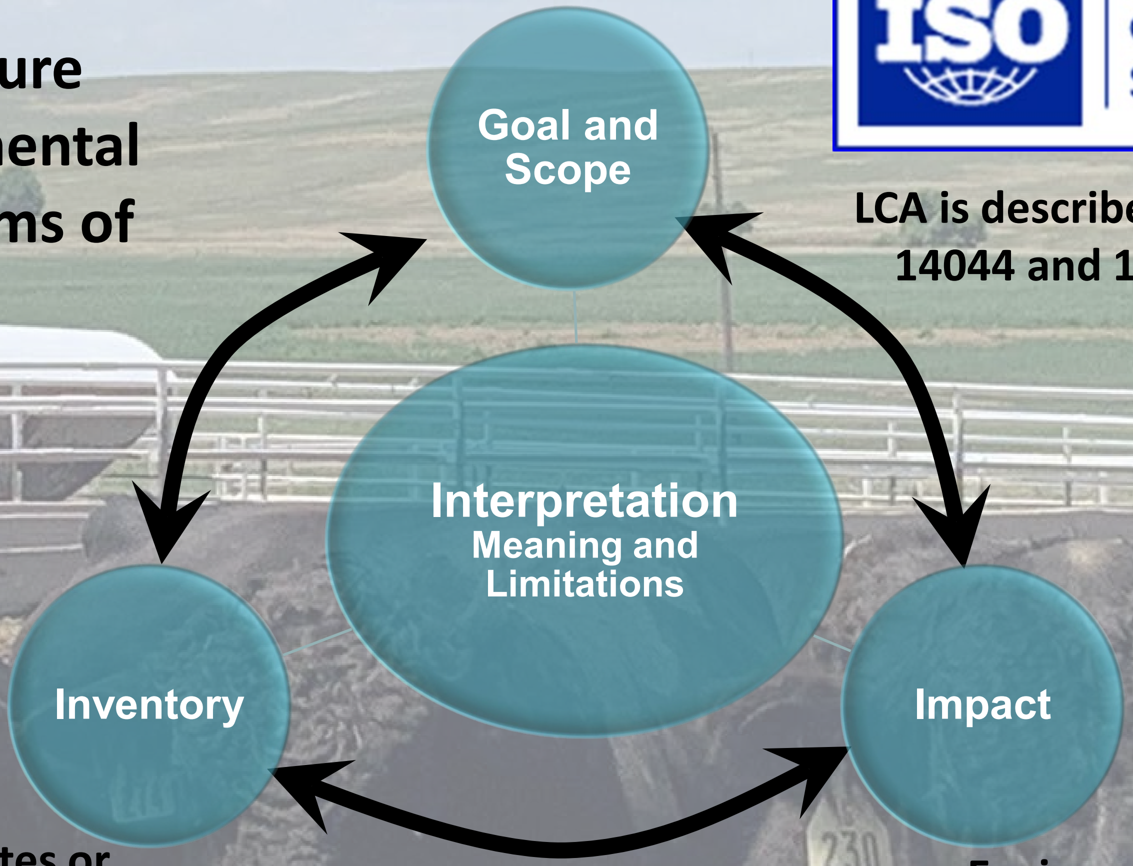
Greg Thoma
University of Arkansas

LCA & Sustainability

Manage What You Measure

What? LCA is a multi-step procedure for calculating the lifetime environmental impact of a product or service in terms of a standardized unit of measure, the functional unit (FU).

- **Why?**
- Product Development / Improvement
    - Selection of best materials or process options (e.g., conservation)
- Identification of 'hotspots' for innovation
- Benchmarking
- Product labels / marketing
- Strategic planning
- Inform public policy



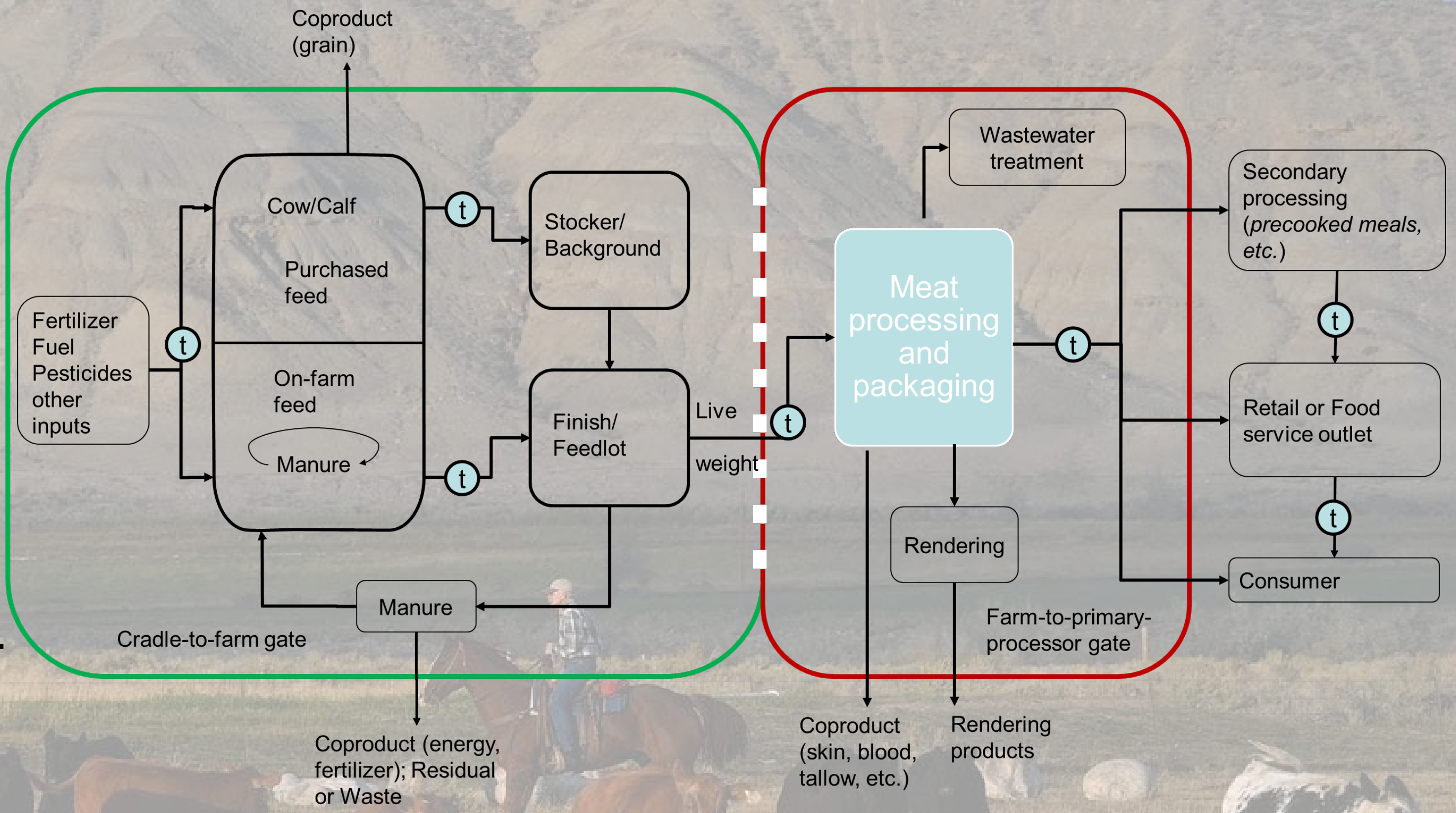
Attributes or characteristics of product or process

Environmental effects of product or process

ISO International Organization for Standardization

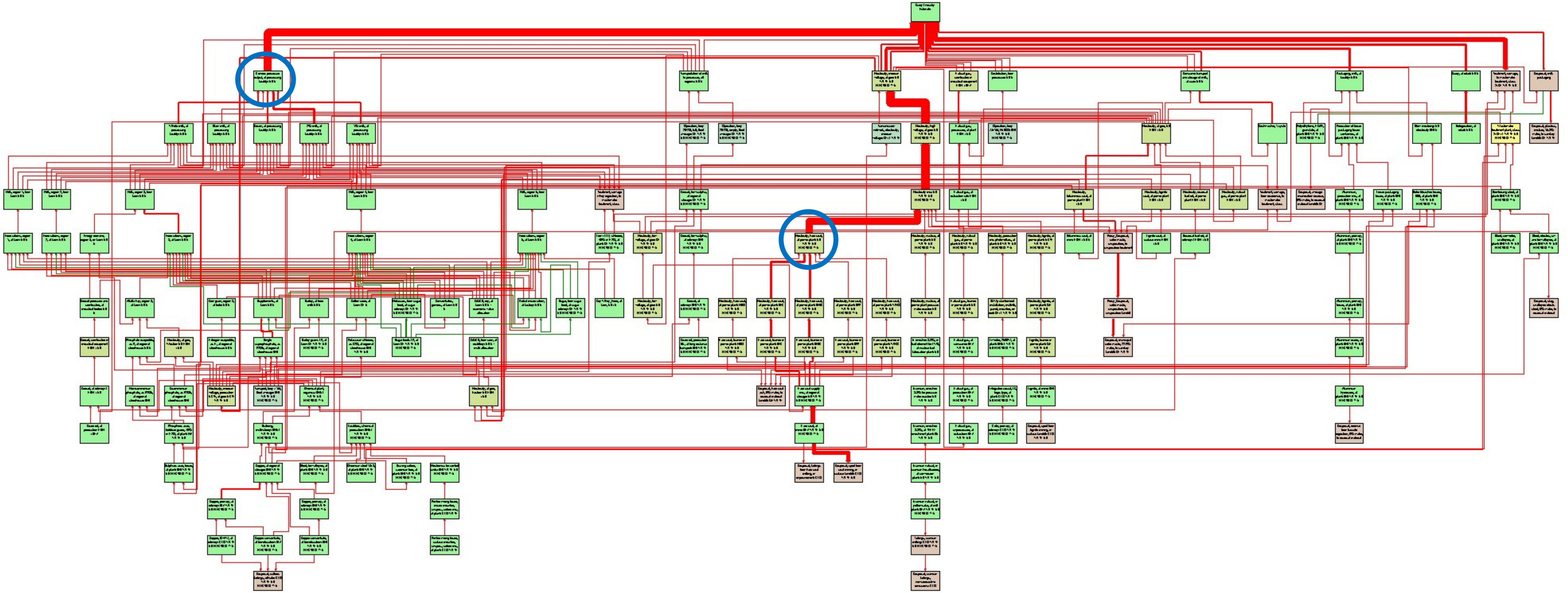
LCA is described in ISO 14040, 14044 and 14046 Standards

LCA Modelling



- **Functional unit (FU)**
- **System boundaries**
  what is included (accounting/legal?).
- **Life Cycle Inventory**
  – extraction of raw resources, primary and secondary production processes, distribution, retail, consumption and EoL.
- **Life Cycle Impact Assessment (LCIA)**
  – 'collapses' the inventory to a manageable set of environmental impacts (e.g., carbon or water footprint)

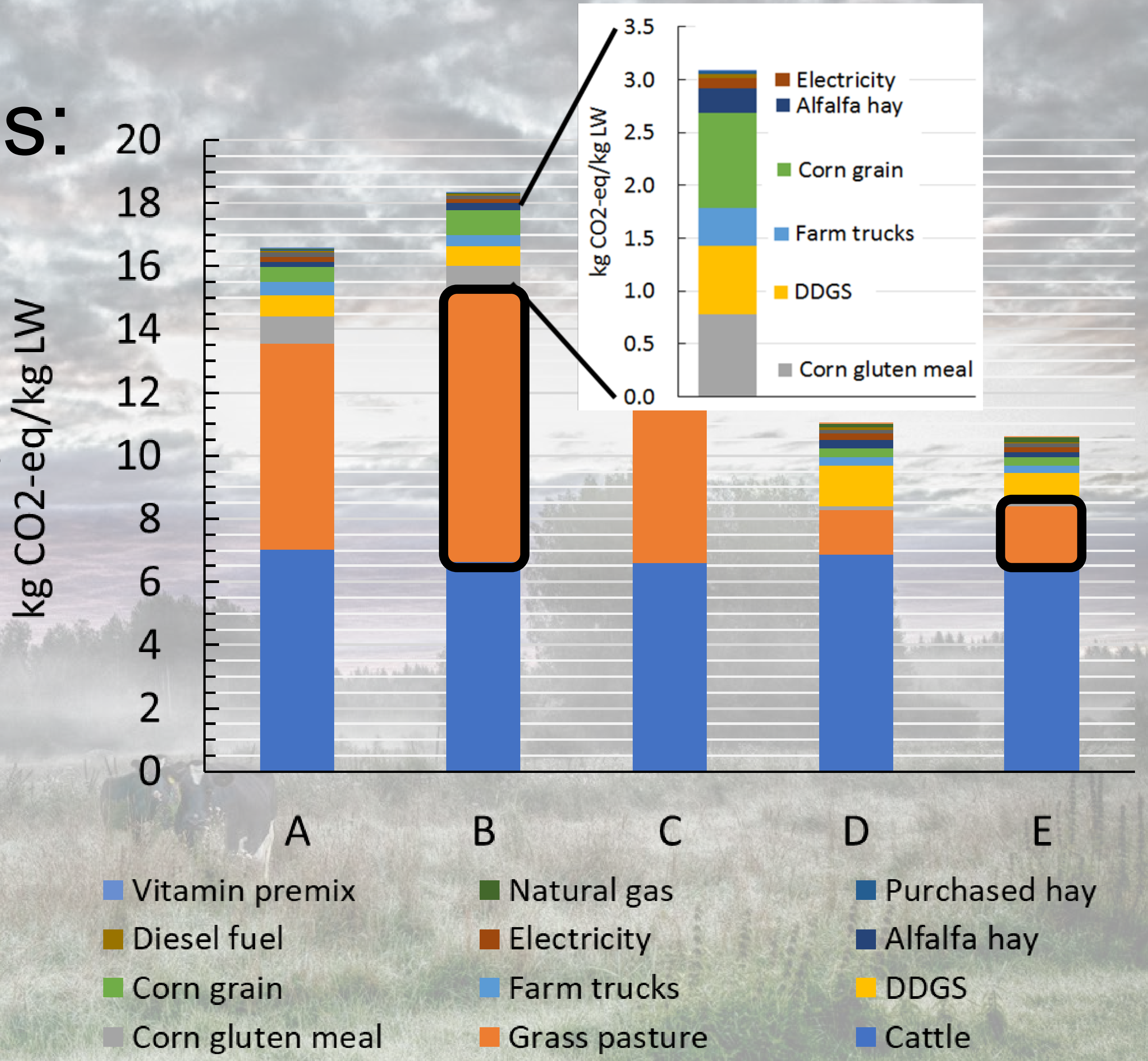
Some Connections are More Important



Leverage points for improvement

Contribution analysis: location matters

- **Matched farm size and practices Differences driven mainly by pasture-related emissions**
  - **Farm B pasture emits ~8X more N_2O per ha than Farm E**
  - **Pasture includes resource use associated with maintenance and emissions resulting from deposited manure and fertilizers**



Limitations

- **Incomplete assessment of:**
  - –Biodiversity
  - –Soil health
  - –Land use / Land use change (especially with regard to urban/peri-urban locations)
- **Continually improving input data/system descriptions**

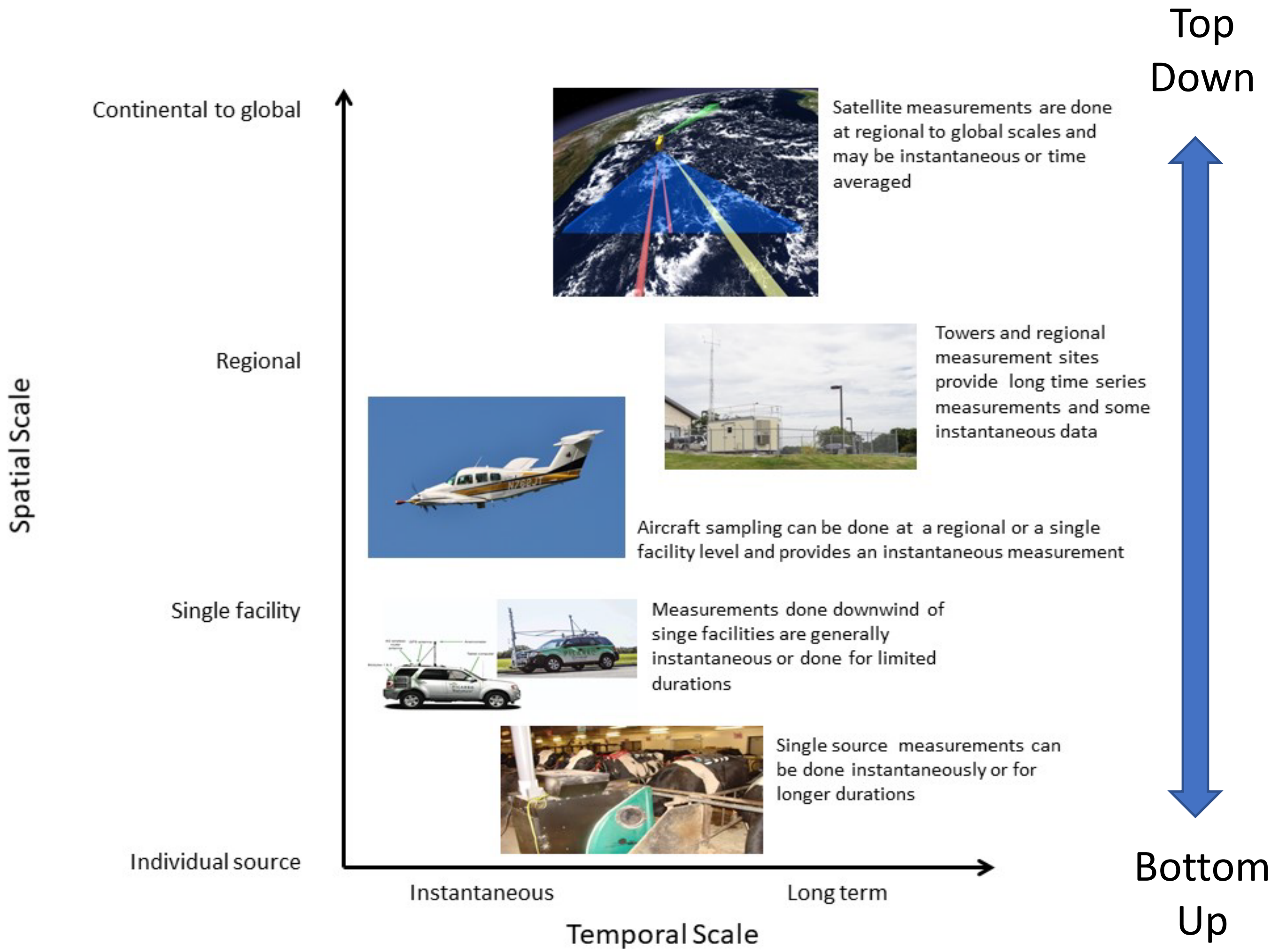
Quantification of Greenhouse Gas Emissions from the System

April Leytem
USDA-ARS, Kimberly, ID

Approaches for Measurements

Top down estimates include emissions from all sources but may have difficulty in attributing emissions to specific sources or source categories.

Bottom up methods provide information about the magnitudes and patterns of emissions from specific sources.



<u>Top Down:</u>

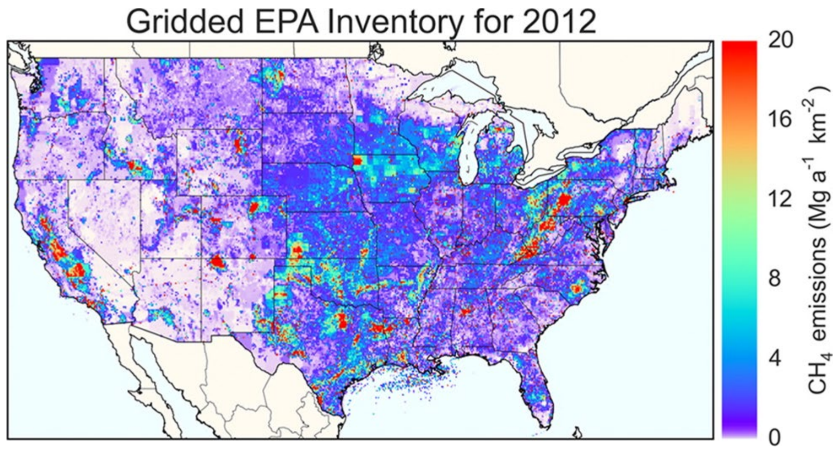
- Remote observatories
- Towers
- Aircraft mass balance
- Aircraft remote sensing
- satellite

<u>Bottom Up:</u>

- point source
- Enclosure (chamber)
- Micrometeorological
- Perimeter facility line
- External tracer
- Inverse dispersion
- Facility scale aircraft/drone

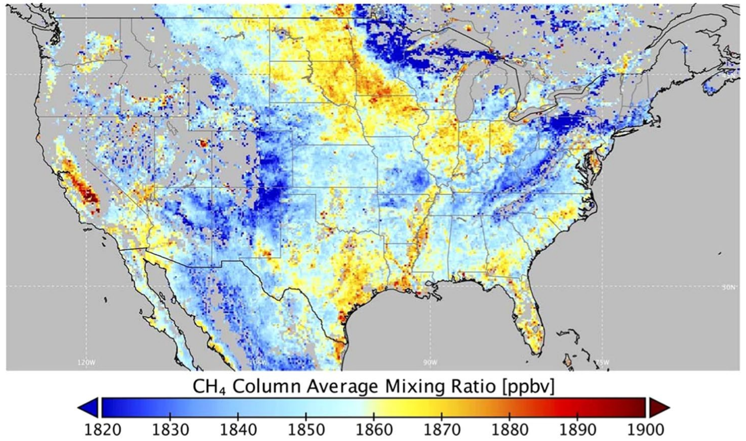
What is the Question/Purpose?

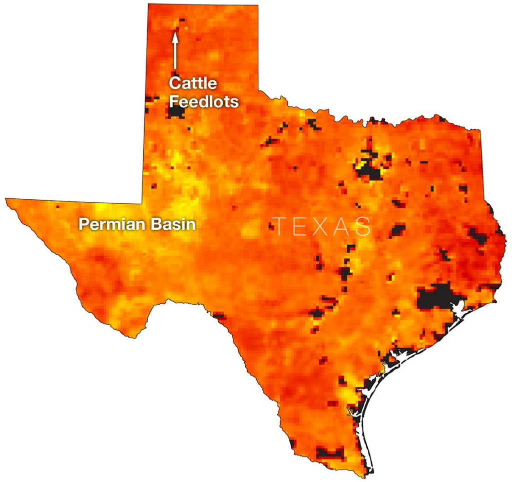
- Baseline emissions – accuracy
- Verification of mitigation – how do we know solutions are working
- Farm scale vs. National Inventory



Things We Have to Consider

- Where do we draw the box? (individual source, facility, regional, national)
- How do we capture variability? (animal to animal/management, daily, seasonal, spatial)





Ultimately the goal is to improve models as we can't make measurements on every farm.

Challenges Related to Quantifying GHG Emissions

Methane

- Measurement of enteric methane in rangeland cattle
    - Need to be able to better predict forage intake and quality
- Methane emissions from manure storage/treatment
- Efficacy of enteric methane mitigation at the herd level and at longer time periods

Nitrous Oxide

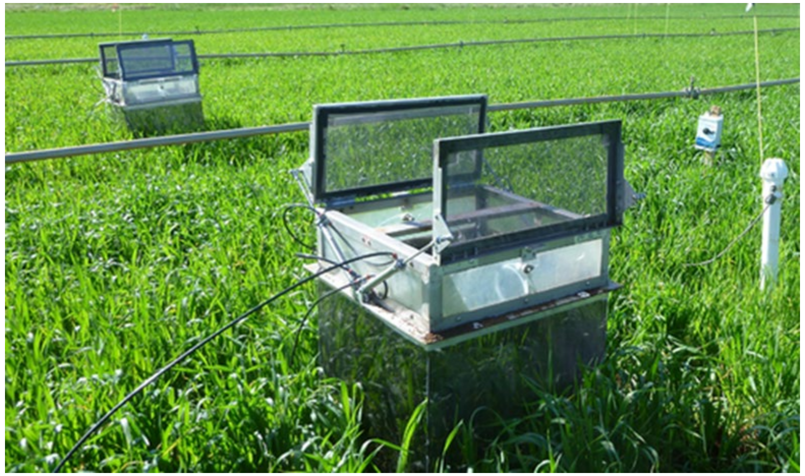
- Measurement of N_2O on rangeland/feedlots/manure storage
- Better emission factors for feed production

Technology

- Instruments with high sensitivity and fast data capture
- Improvement of satellite retrievals/algorithms

Modeling/Inventory

- Improved process-based models for estimating system GHG budgets etc.
- Better activity data



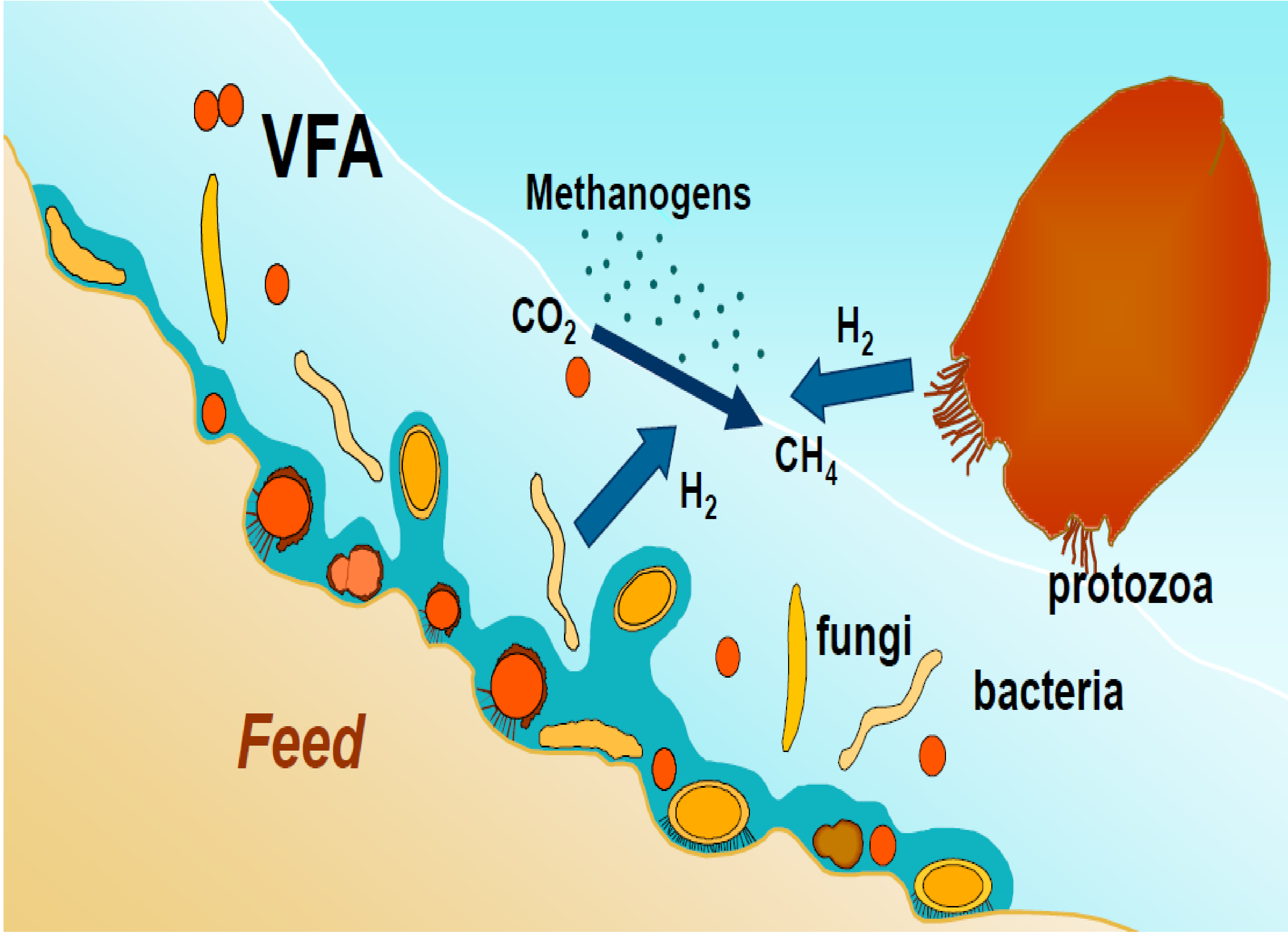
Methane Mitigation Strategies

Kristin Hales
Department of Animal and Food Science
Texas Tech University

- Methane (CH_4) production is a microbially driven process to remove hydrogen from the rumen

  $4H_2 + 2\ CO_2 \rightarrow CH_4 + 2H_2O$

- 2 to 12% of intake energy is lost as CH_4
- 6 to 10% on forage-based diets
- 2.5 to 4% on grain-based diets



Huhtanen, SLA

Expressing Methane Production

- Total Production (grams/day, liters/day)
  - Mainly influenced by intake
  - Positively correlated to production
- Methane Yield (grams/kg DMI, % of intake
  Describes CH_4 per unit of intake
  - Decrease as feeding level or intake increase
  - Biologically more correct than total CH_4
- Methane Intensity (grams/unit of product, grams/kg of red meat yield)
  - Mainly influenced by production level
  - Practical target to reduce CH_4 per unit of product
  - Life cycle analysis, takes longevity into account

GHG efficiency = $\frac{\text{kg meat/milk}}{\text{ton of } CH_4 \text{ produced}}$

CAUTION

Use the correct denominator!

GHG production should be viewed as an investment!

	Seaweed	3-NOP	Nitrate	Genetic Selection	Vaccine	Management Strategies
Animal production	↓	Little change	Little change	??	??	↑
Methane, g/day	↓	↓	↓	Unlikely, not directly	Success unknown	↓
Methane, g/kg HCW	↓	↓	↓	??	??	↓
Long term monitoring	147 days	115 days	90 days	Early stages	??	Life cycle analyses ongoing
Status	Lack of largescale cultivation of seaweed	Not FDA approved in U.S.	Experimental, acclimation is critical	Research ongoing	Research ongoing	Research ongoing
Scalability	Unlikely to be successful, decreases in HCW (20 lb)	Unknown	Unlikely to be successful, may increase N_2O	Unknown	Unknown	Ongoing for 30+ years

Technologies to Decrease Enteric Methane

Diet Optimization

- Increase starch concentration
- Added fat
- Grain processing
- Grasses vs. legumes
- Increase forage quality

Genetic Selection

- High vs. low CH_4 production
- Selection for efficiency

Microbiome Manipulation

- Alter rumen to decrease CH_4
  - Vaccine

Management Strategies

- Technologies that increase growth and carcass weight
  - Ionophores, implants, β-agonists
  - Decrease days on feed
- Increase reproductive efficiency of cow herd
  - Decrease open cows
  - Increase longevity of mature cows
  - Moderate cow size and mature wt

Are these mitigation strategies additive?

Carbon Sequestration and Rangelands: State of the Science and Opportunities

Justin Derner

Justin.Derner@usda.gov

United States Department of Agriculture
Agricultural Research Service

Characteristics of Rangelands

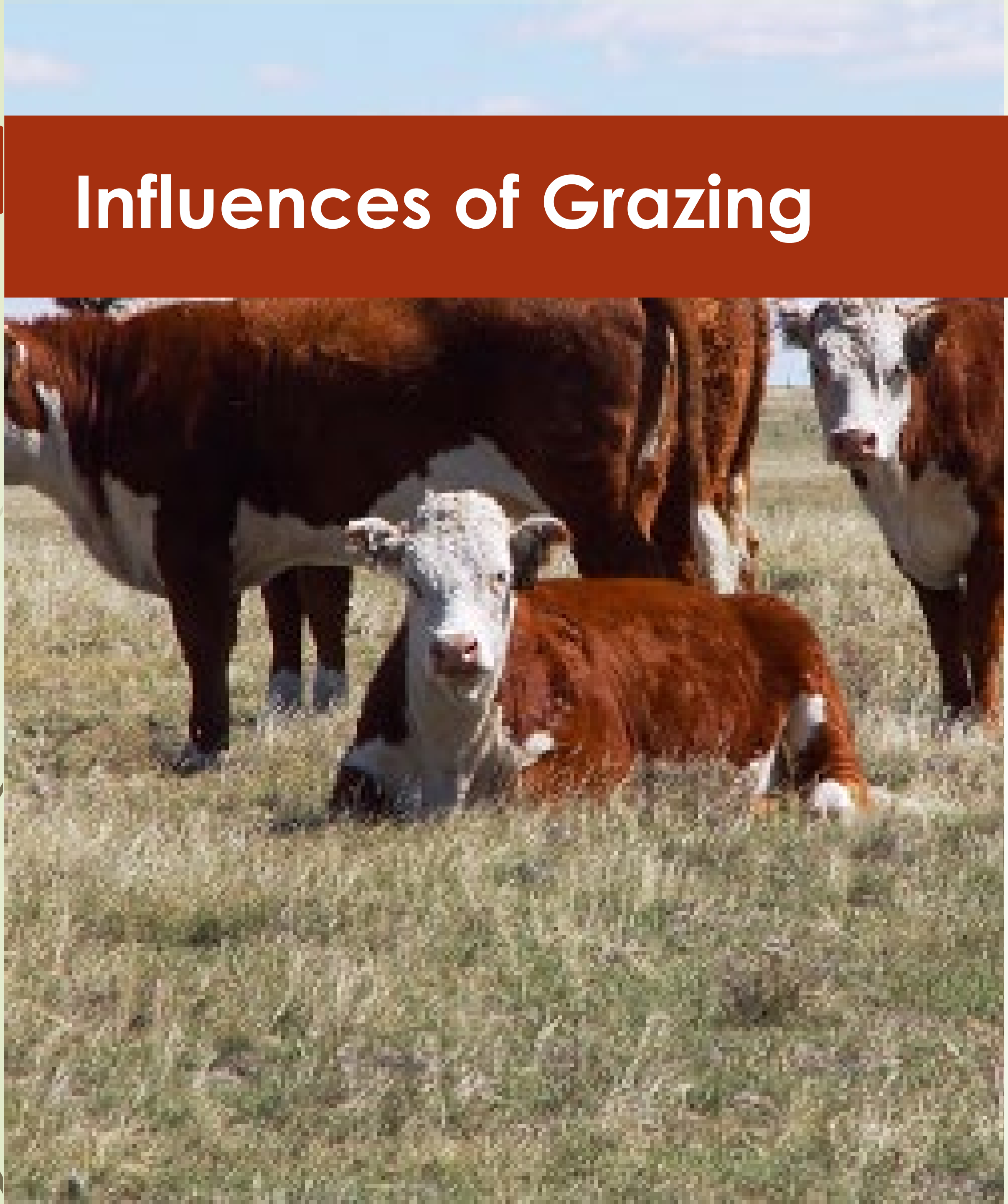
- High degree of spatial and temporal variability
- Ecosystem C storage mostly in soil organic matter
- Slow vegetation change
  - Decadal scales
  - *Porensky et al. 2016*
    Journal of Applied Ecology
  - *Porensky et al. 2017*
    Rangeland Ecology & Management

Influences of Weather/Climate

- Sink when wet; source when dry
- 2-4 months period of C uptake
  - Rest of year is "in balance" or losing C
  - Management during uptake period is critical
- Low sequestration rates on rangelands with native vegetation

- *Sanderson et al 2020*
  Journal of Soil and Water Conservation
- *Morgan et al. 2016*
  Rangeland Ecology & Management
- *Svejcar et al. 2008*
  Rangeland Ecology & Management

Influences of Grazing

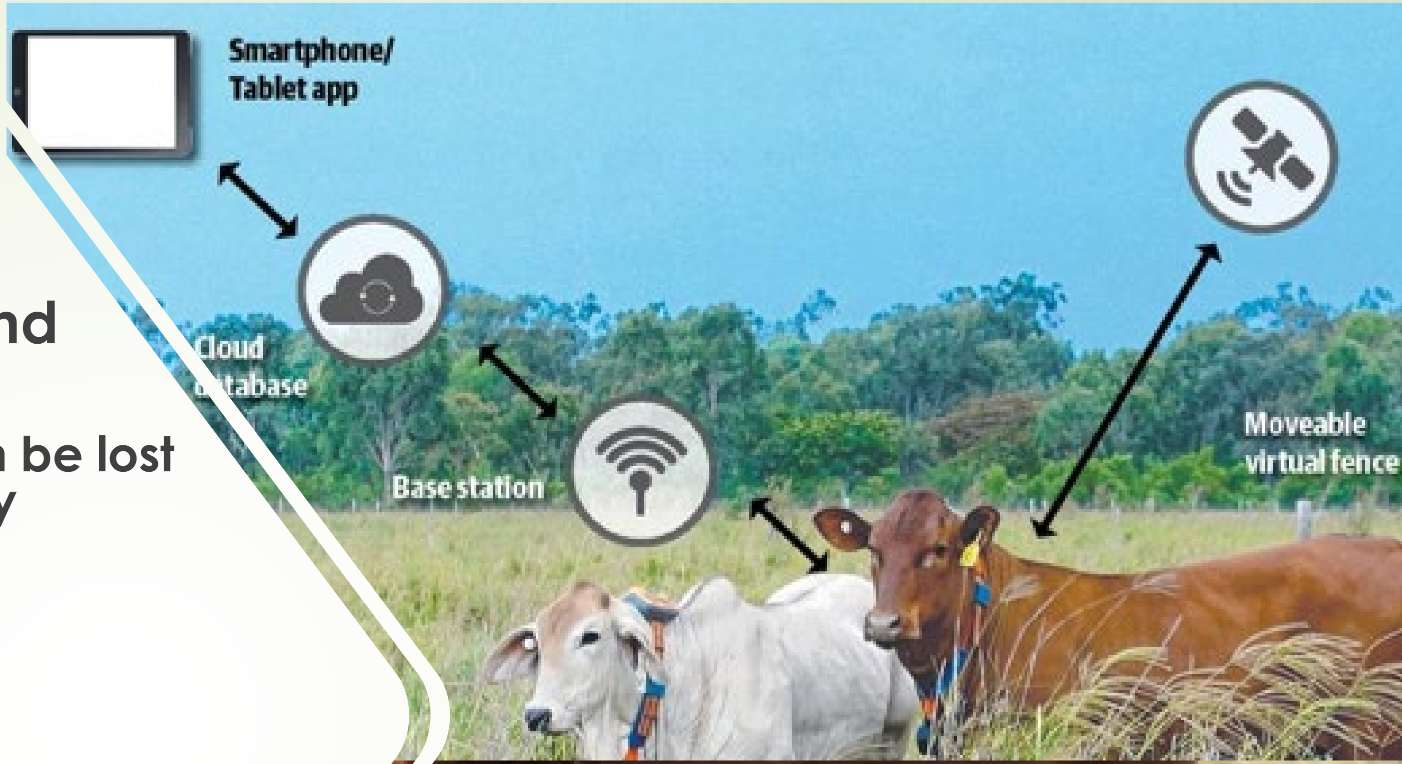


- **Global synthesis of grazing effects: highly variable**
  - *Milchunas and Lauenroth 1993 Ecological Monographs*
  - *McSherry and Ritchie 2013 Global Change Biology*
- **No grazing effect after 80 years in shortgrass prairie**
  - *Derner et al. 2019 Ecosystems*

Opportunities

Sanderson et al. 2020
Journal of Soil and Water Conservation

- Keep rangelands intact and minimize losses
  - Large amounts of soil C can be lost when rangelands are poorly managed or converted.
- Emphasize adaptive management
  - Co-provide vegetation heterogeneity, grassland bird habitat, and fuels reduction outcomes through combining virtual herding with advanced remote sensing for near-real time forage conditions.
- Restore prior cultivated and degraded lands
  - Integrate livestock grazing and cropping systems.

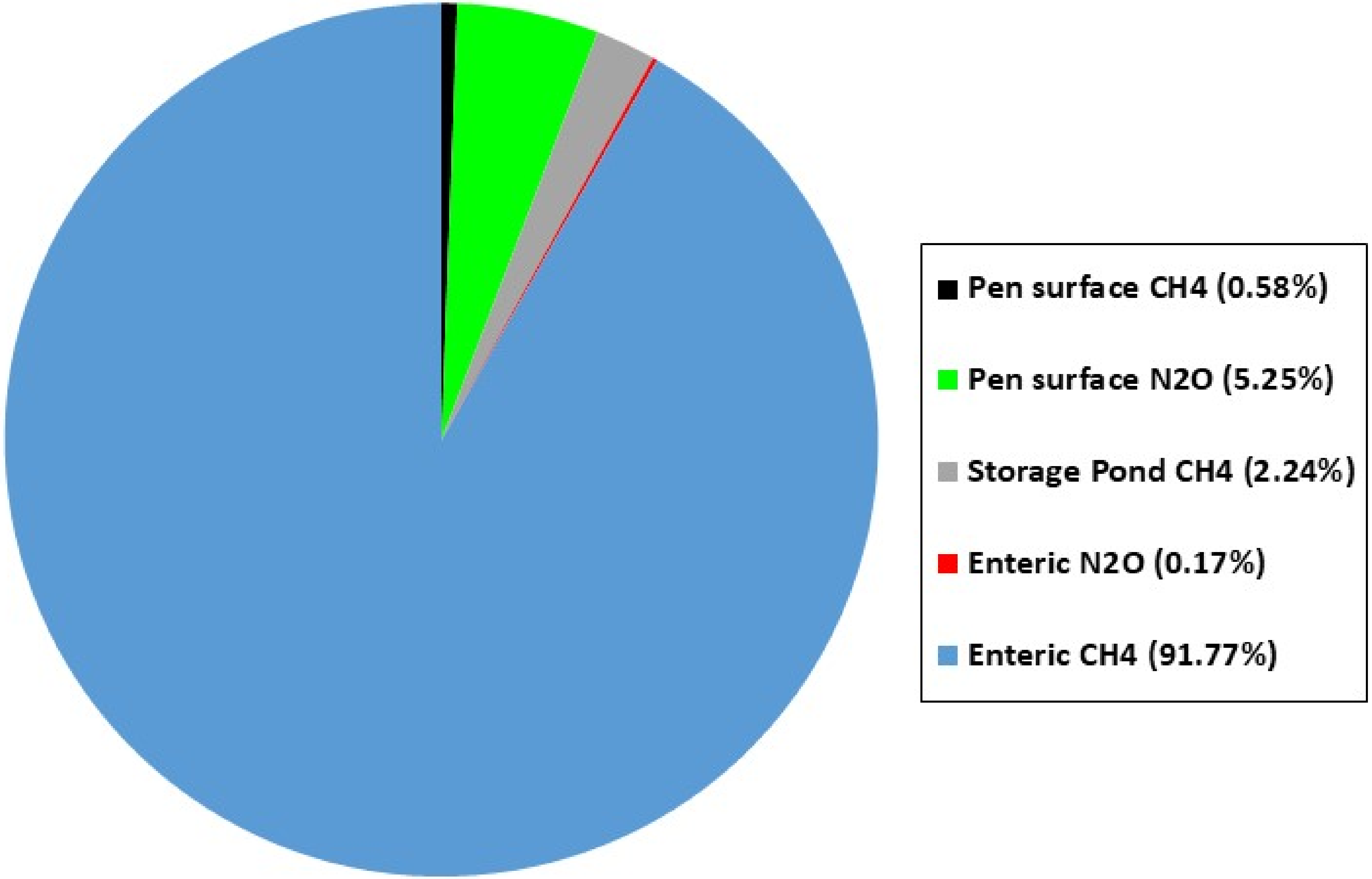


Brent W. Auvermann, Professor and Center Director

Amarillo, TX

Relative Contributions to Feedyard CO_2e Emissions

Parker *et al*. (2021), *Transactions of the ASABE* 64(6):1781-1794

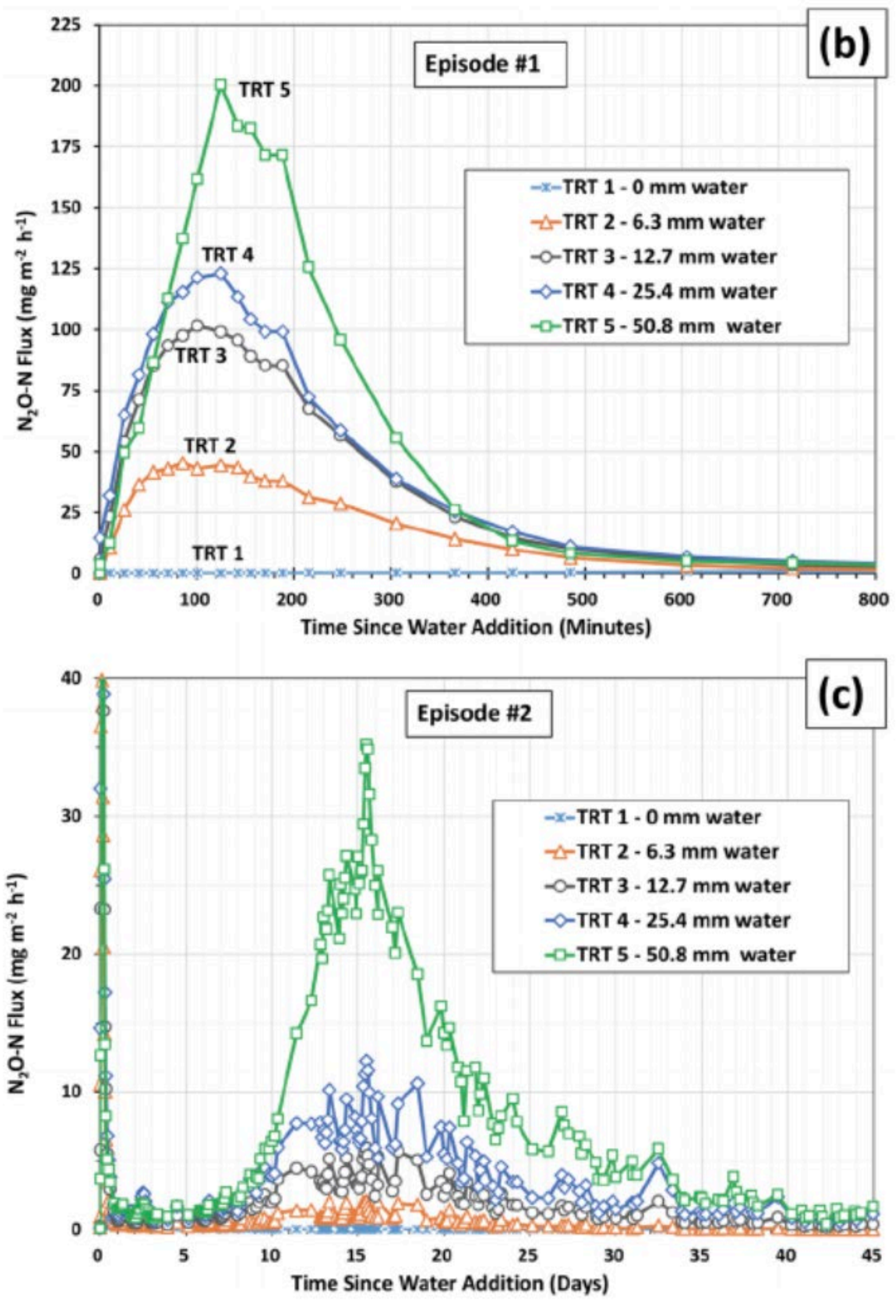


Texas A&M AgriLife Research

In Vitro: Two Distinct Peaks

Parker *et al*. (2017), *JEQ* 46(4):733-740

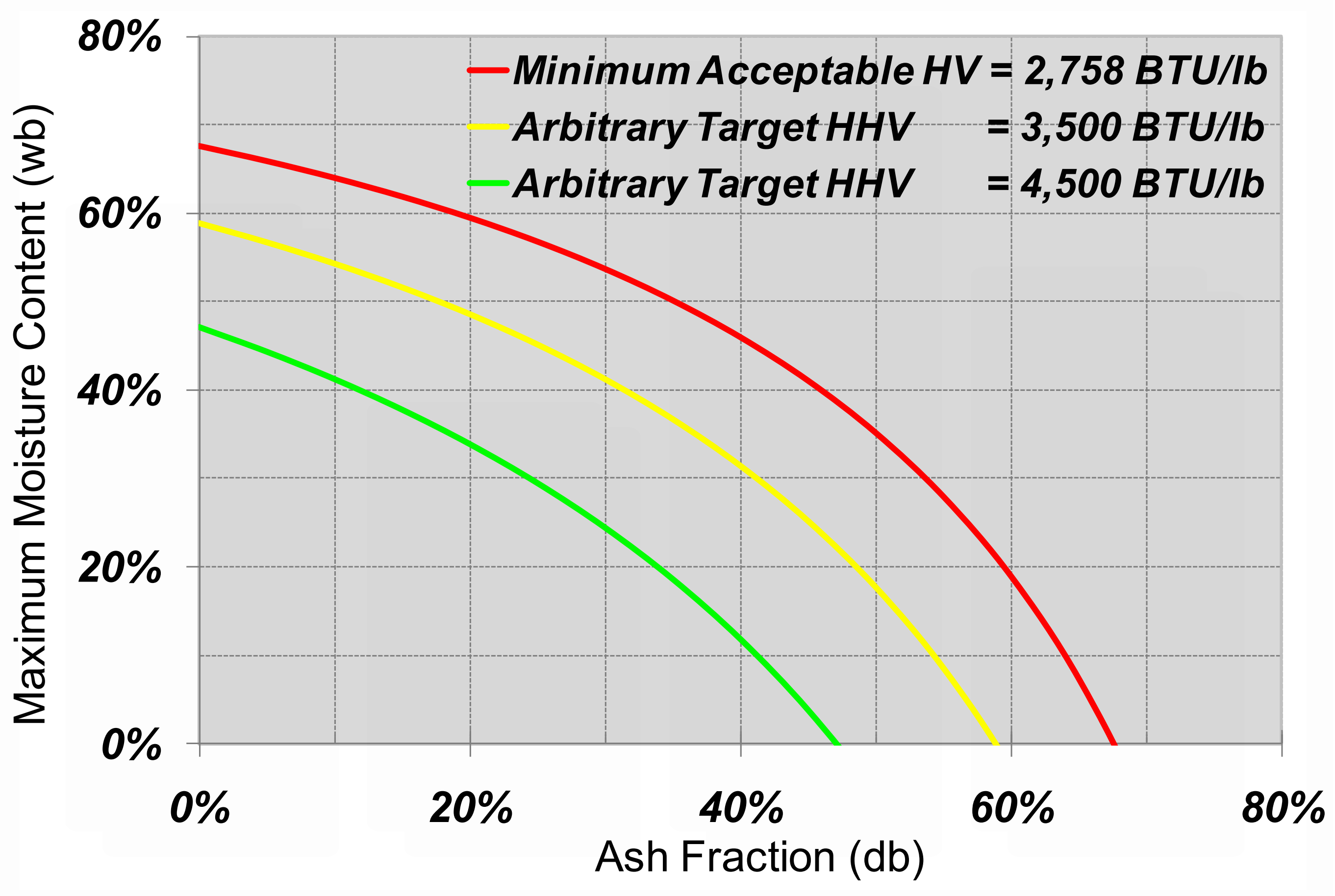
- Peak #1
  - 2-6 hours after sim. rainfall
  - Low cumulative mass emitted
- Peak #2
  - 10-35 days after sim. rainfall
  - High cumulative mass emitted
- If we need to reduce N_2O from the corral surface…?



Biomass Energy

A Cautionary Tale…*and* an Opportunity

- If carbon markets in some form are here to stay, however…
- Upper limit* on fuel value of feedyard manure: ~8,500 Btu/lb (DAF)
  - Water and ash are manure pollutants
  - DAF suggests advanced management approaches
  - Corral-surface management – keep it DAF!
  - Novel housing systems – keep it DAF!



TEXAS A&M AGRILIFE RESEARCH

ENVIRONMENT

SOMETHING IN THE AIR

In the Texas Panhandle, which produces a fifth of the U.S. beef supply, communities are being choked by fecal dust from nearby feedlots. The state's regulatory agency isn't doing anything about it—and it's about to get a whole lot worse.

by **CHRISTOPHER COLLINS**

FEBRUARY 3, 2020, 6:00 AM, CST

A version of this story ran in the January / February 2020 issue.

"We're just against feedyards that can't take care of their dust or their smell. *It should stop at their fence line*."

- A neighbor

Texas A&M AgriLife Research

The need to think about system-wide, scalable solutions

John Ritten

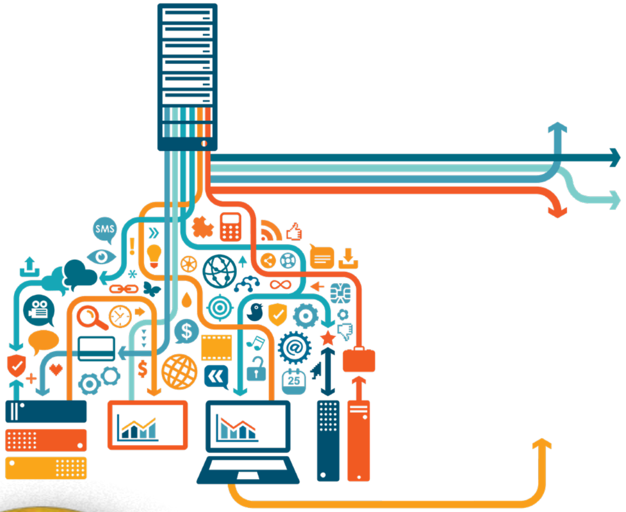
Ag and Applied Economics

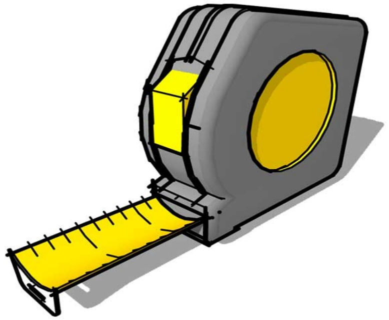
University of Wyoming

Need to find Scalable, System-Wide Solutions

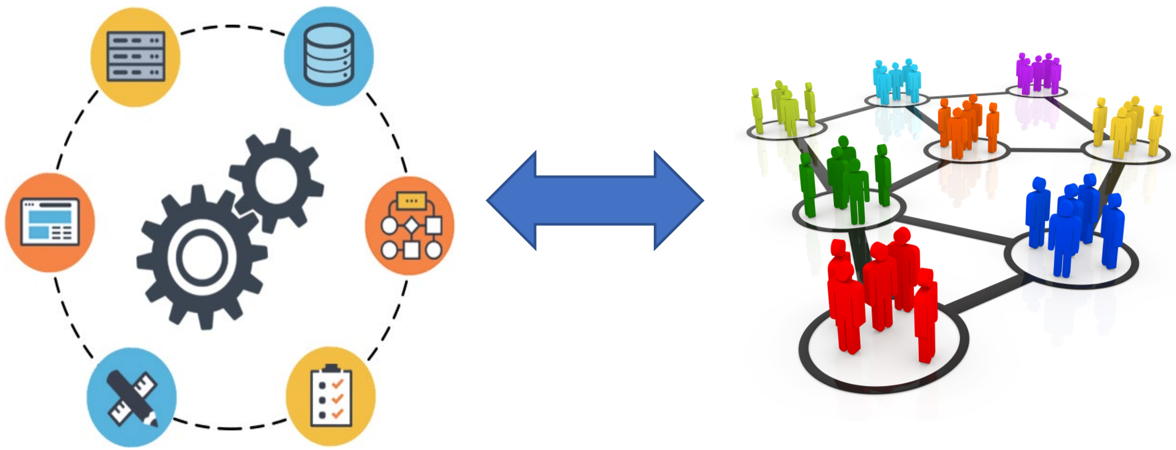
Don’t let GHG distract existing goals –
Need to find *synergistic* solutions

Focus needs to be from cradle to plate -
We need to coordinate and integrate

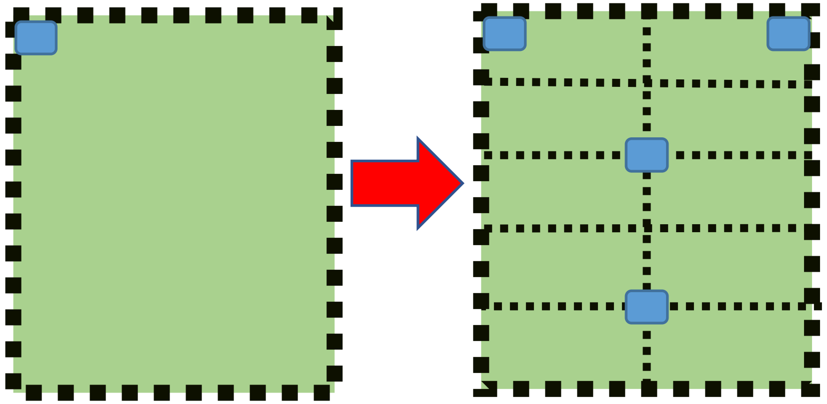




We will only ***manage*** what we ***measure***. Need to spend time understanding systemic trade-offs!



Unintended Consequences *Across* the Supply Chain



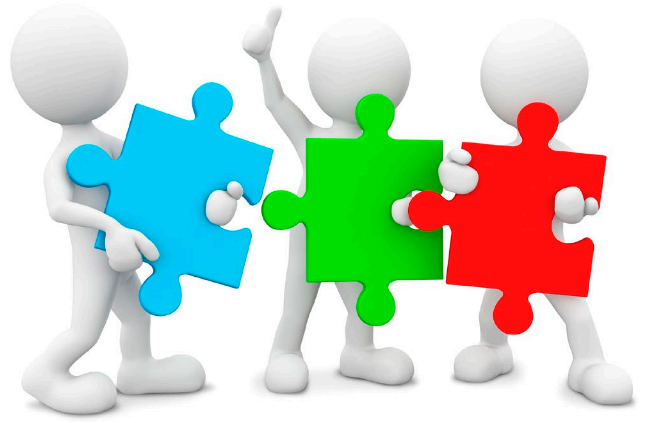
-$127,000 *NPV* over 35 years for Cow/calf operation, Dyer et al., 2021

$2,000 - $36,000 increase in infrastructure costs, ***$8 - $210 per steer***, Windh et al., 2019

Tech may help, but we're not ready yet–
Fousti et al., 2021

We need to understand the impacts to ***OUR*** suppliers and customers

Correlation ~.5 for RFI in sheep when comparing grain- and forage-based diets - Ellison et al., *currently in review*



BEEF as a <u>BRAND</u>!

≠ Levi's®

Most consumers don't know which 'brand' of beef they are buying

Can't sacrifice one sector – **'BEEF'** is <u>*ALL*</u> sectors

Need to understand incentives **ACROSS** the supply chain

Legislation can provide needed regulatory <u>*framework*</u> – questions around: baselines, additivity or maintenance, outcomes vs practices, time and who takes on risk

Thank You!

UNIVERSITY OF WYOMING

- John Ritten
- University of Wyoming
- Department of Ag and Applied Economics
- john.ritten@uwyo.edu

AgNext

COLORADO STATE UNIVERSITY

RESEARCH SUMMIT

SHAPING THE FUTURE OF SUSTAINABILITY IN ANIMAL AGRICULTURE

FIVE RIVERS

CATTLE FEEDING

Presenting today

Clinton van der Spuy

Head of Risk Management, Financial Markets

Tom Bailey

Senior Analyst, Consumer Foods & Food Service

Tierney Seidel

Sustainable Capital Markets

Rabobank

ESG and Sustainable Lending Revolution

Where is this moving in the future?

Rabobank

Who is Rabobank

Here today

Clinton van der Spuy

Head of Risk Management, Financial Markets

Tom Bailey

Senior Analyst, Consumer Foods & Food Service

Tierney Seidel

Sustainable Capital Markets

Rabobank

What is Sustainable Lending?

Use of Proceeds

GREEN BOND/LOAN
SOCIAL BOND/LOAN
SUSTAINABILITY BOND/LOAN

KPI-Linked

SUSTAINABILITY-LINKED BOND/LOAN

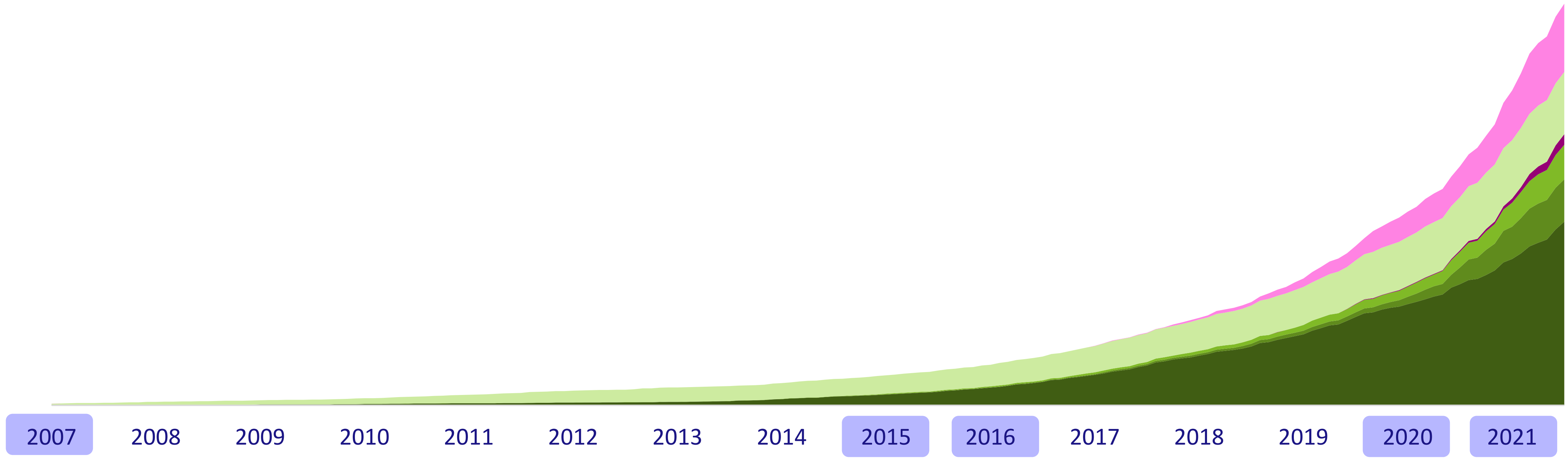
Rabobank

Best Practices

- SUSTAINABILITY-LINKED, GREEN AND SOCIAL LOAN PRINCIPLES
- GREEN, SOCIAL, SUSTAINABILITY, SUSTAINABILITY-LINKED BOND PRINCIPLES
- EU GREEN BOND STANDARD AND EU TAXONOMY

Rabobank

Market Evolution



European Investment Bank

PARIS CLIMATE AGREEMENT

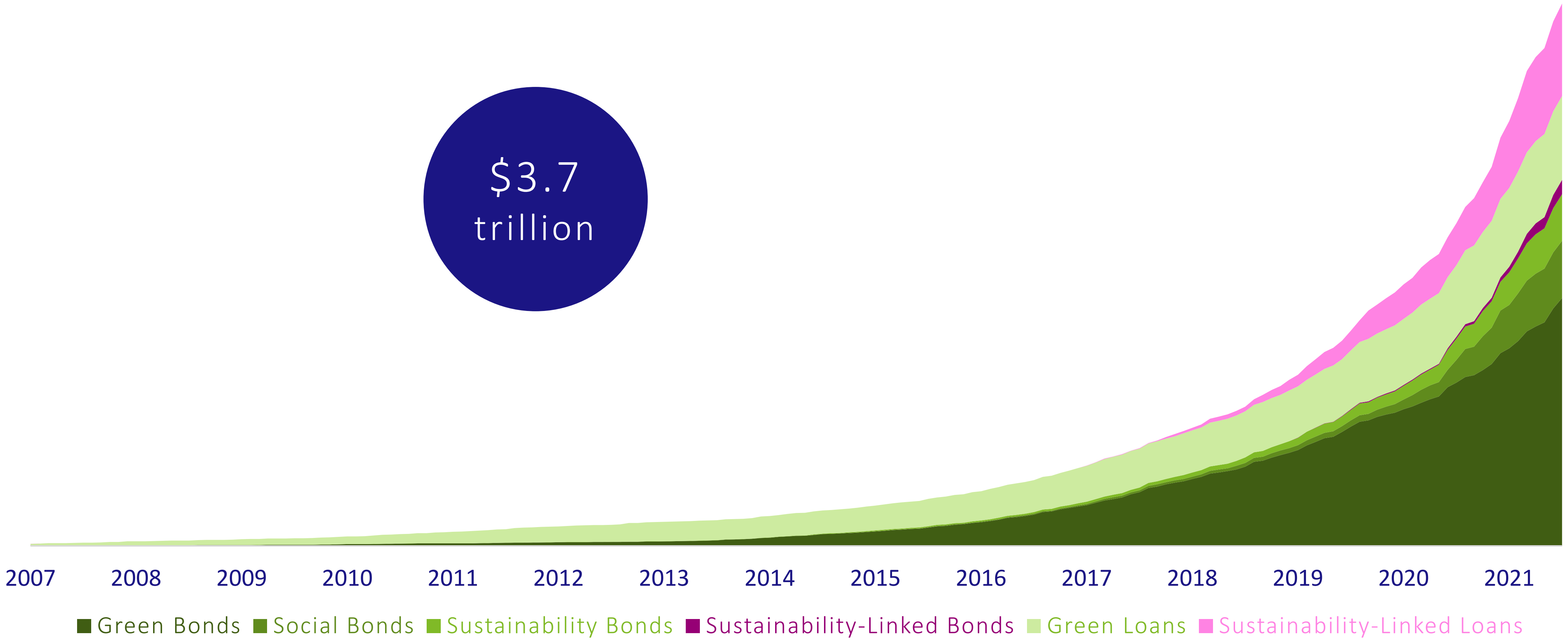
UN CLIMATE CHANGE CONFERENCE UK 2021

■ Green Bonds ■ Social Bonds ■ Sustainability Bonds ■ Sustainability-Linked Bonds ■ Green Loans ■ Sustainability-Linked Loans

Source: Bloomberg NEF

Rabobank

Where are we now



Source: Bloomberg NEF

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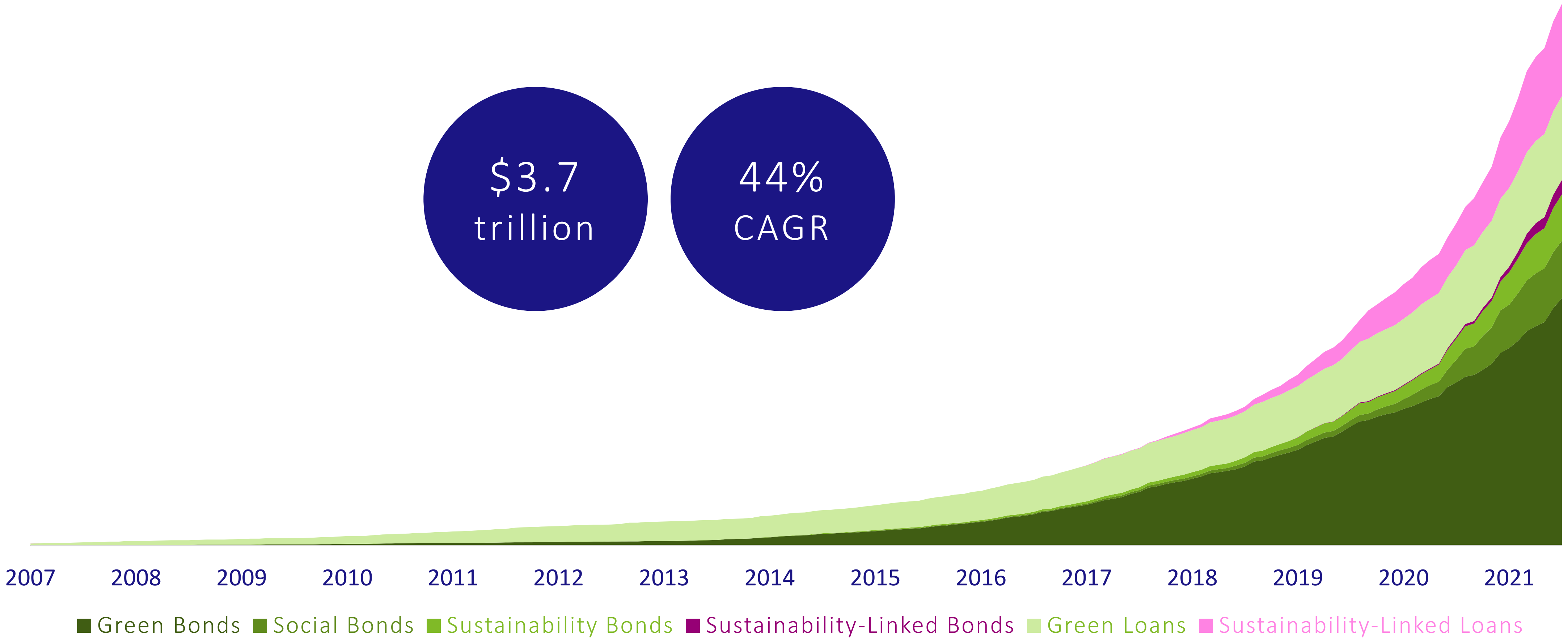
Where are we now

$3.7 trillion

44% CAGR



Source: Bloomberg NEF

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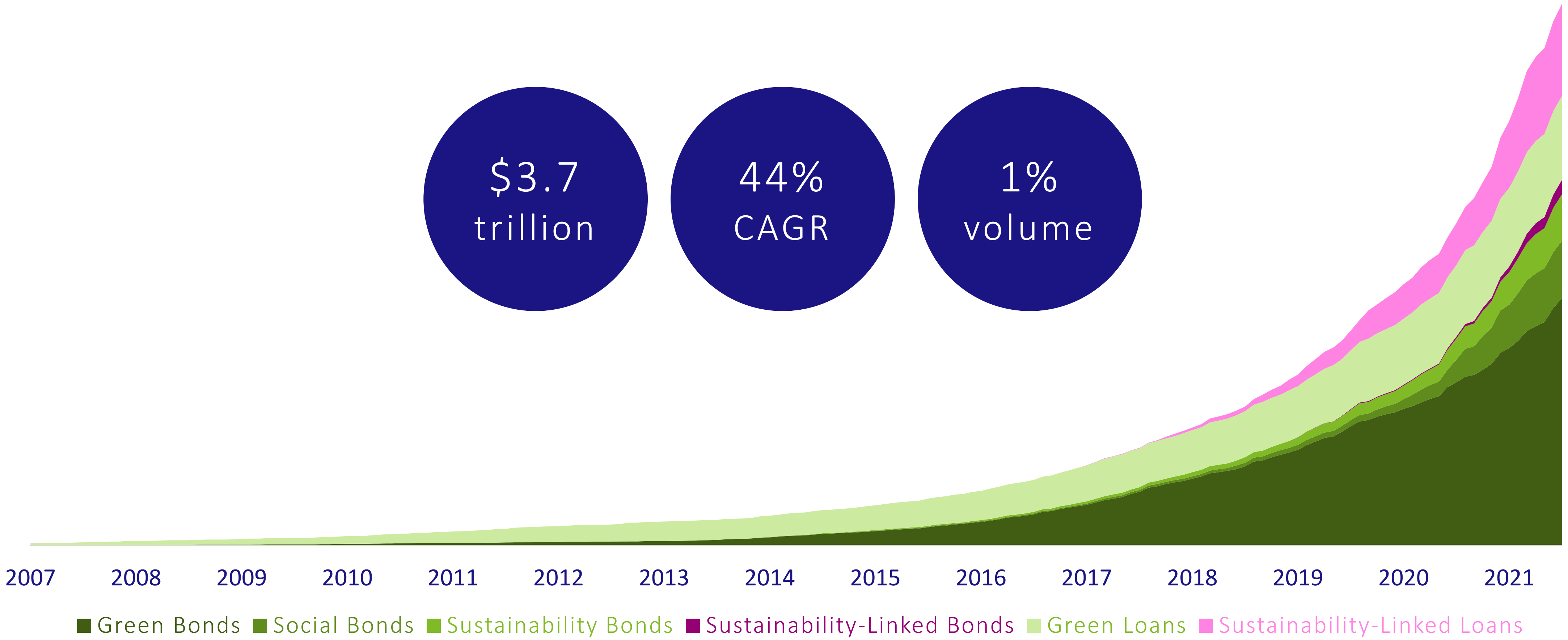
Where are we now



Source: Bloomberg NEF

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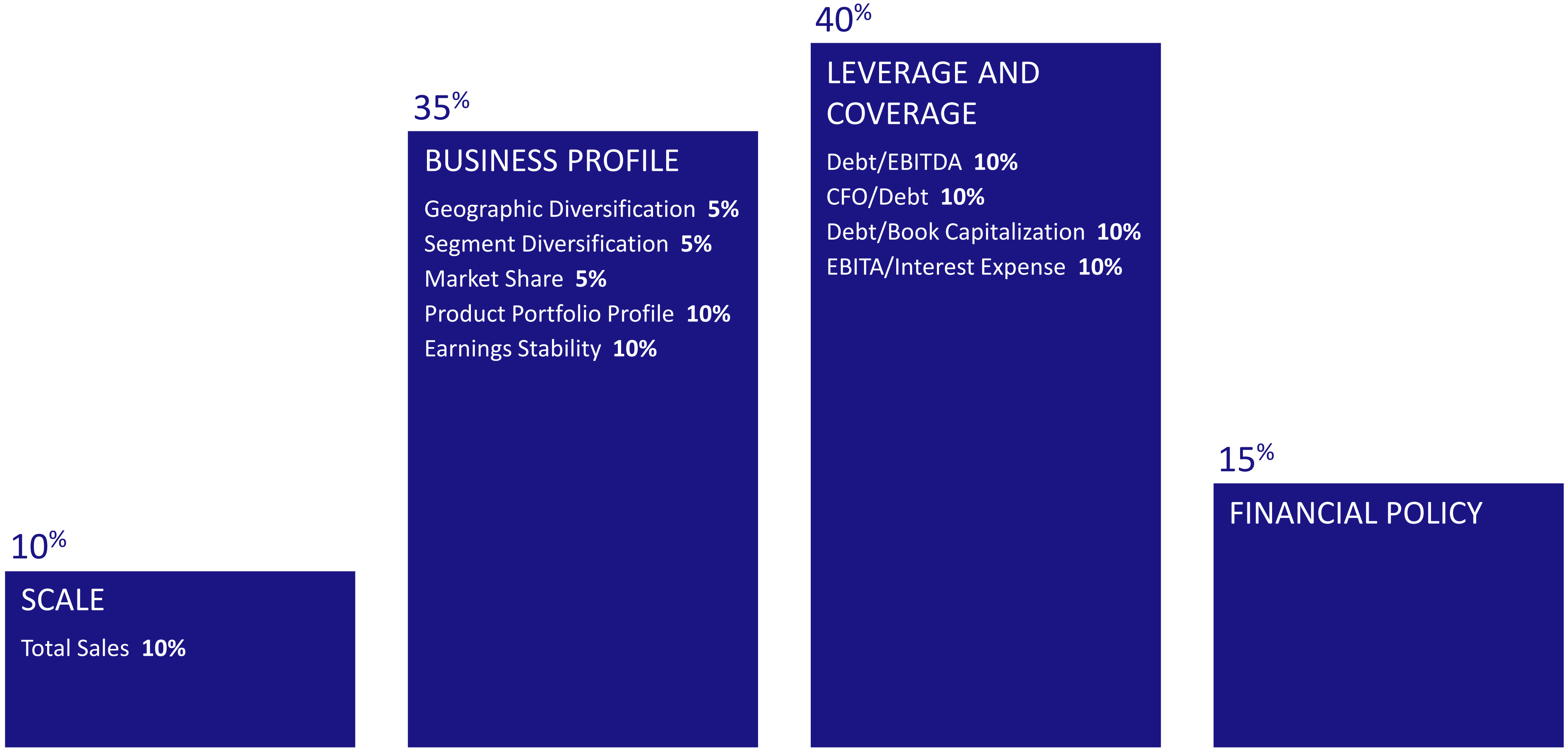
Existing risk frameworks…



Source: Moody's Investors Service

Rabobank

…need to integrate ESG factors

(especially climate risks)

Physical risks (acute & chronic)

Transition risks

Source: Financial Stability Board

Rabobank

…need to integrate ESG factors

(especially climate risks)

Physical risks (acute & chronic)

E.g.,

Transition risks

Source: Financial Stability Board

…need to integrate ESG factors

(especially climate risks)

Physical risks (acute & chronic)

E.g.,

- Flooding
- Drought
- Sea Level Rise
- Heat Stress

Transition risks

E.g.,

- Policy
- Technology
- Market
- Reputation

Source: Financial Stability Board

Rabobank

…need to integrate ESG factors

(especially climate risks)

Physical risks (acute & chronic)

E.g.,

- Flooding
- Drought
- Sea Level Rise
- Heat Stress

Transition risks

E.g.,

- Policy
- Technology
- Market
- Reputation

Source: Financial Stability Board

Rabobank

Core Elements of TCFD

Source: Financial Stability Board

How are consumers thinking?

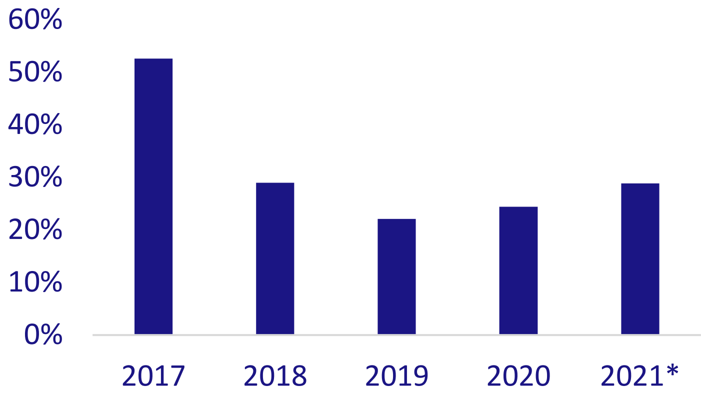
Rabobank

How are consumers thinking?

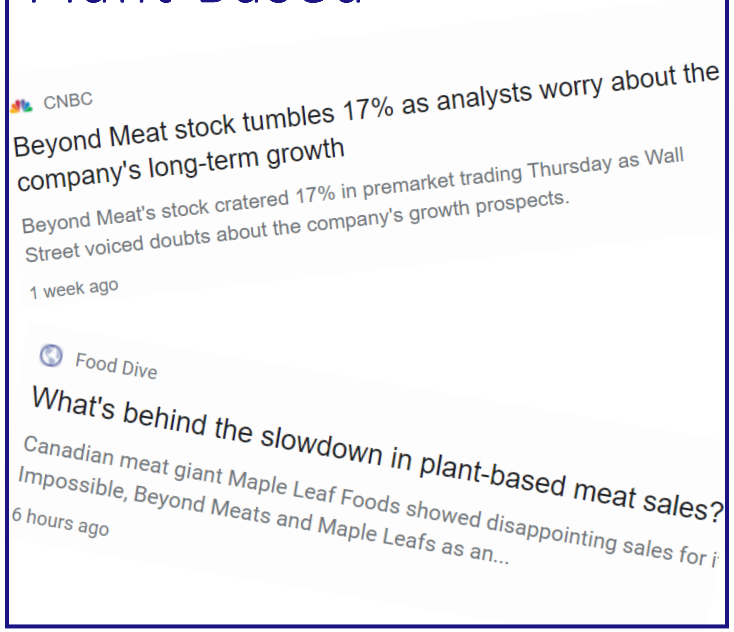
So far, they are more bark than bite…

Animal Welfare

Fairlife Sales
(YOY growth in sales value)



Plant Based


CNBC

Beyond Meat stock tumbles 17% as analysts worry about the company's long-term growth

Beyond Meat's stock cratered 17% in premarket trading Thursday as Wall Street voiced doubts about the company's growth prospects.

1 week ago

Food Dive

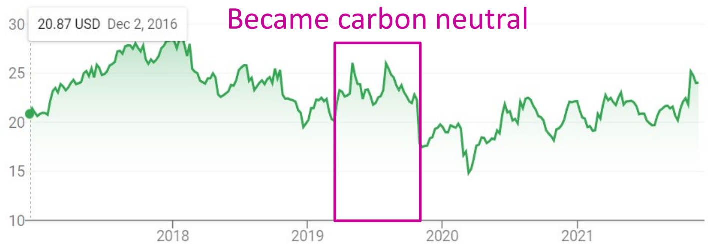
What's behind the slowdown in plant-based meat sales?

Canadian meat giant Maple Leaf Foods showed disappointing sales for i… Impossible, Beyond Meats and Maple Leafs as an...

6 hours ago

Carbon neutral

Maple Leaf Share Price



Pressure to take action is coming from every angle

Governments and regulators

China's net-zero target is a giant step in fight against climate change

All countries can now build systems at costs no higher than for fossil fuels

Democrats Propose a Border Tax Based on Countries' Greenhouse Gas Emissions

Senators introduced a plan on Monday to tax iron, steel and other imports from countries without ambitious climate laws.

G20 ministers endorse carbon pricing to help tackle climate change

ECB president Christine Lagarde calls for mechanism that reflects 'true cost of carbon'

// EU's Fit for 55 package | 13 measures to reduce EU GHG emissions by 55% in 2030 over 1990 levels| carbon pricing expanding

Investors and banks

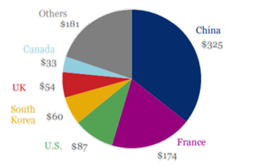
ECB presents action plan to include climate change considerations in its monetary policy strategy

8 July 2021

Key elements of the 2021 Biennial Exploratory Scenario: Financial risks from climate change

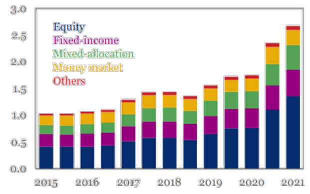
ⓘ The 2021 Biennial Exploratory Scenario will explore the resilience of the UK financial system to the physical and transition risks associated with different climate pathways.

Chart 4: The climate-aligned bond universe* has grown close to $1 trillion in size



Source: IIF, Climate Bonds Initiative; *Non-ESG labelled bonds issued by companies that derive a signficant portion of their revenue streams from climate-aligned activities AND finance activities that are identified as climate-aligned

Chart 1: The ESG fund universe has topped $2.5 trillion



Source: IIF, Morningstar

Consumers

Nov 10, 2020, 12:00pm EST | 10,861 views

Sustainable Food Trends Will Become Center Of The Plate With Modern Consumers

Retailers

PRESS RELEASE • JUL 31, 2020 12:00 AM

Ahold Delhaize to halve carbon emissions from operations and reduce value chain emissions in coming decade

Tesco commits to net zero emissions from its supply chain and products by 2050

24 September 2021

DIVE BRIEF

Ahold Delhaize moves up net-zero pledge

Published Nov. 15, 2021

Rabobank

Three Scopes

Scope 1

Emissions from factory boilers or company car

Scope 2

Electricity used in the factory

Scope 3

Emissions from growing sugar, wheat and cocoa, from transportation to supermarket, packaging and waste

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Scope 3

Recent Sustainability-Linked Bond

KPI:
Reduction of Scope 1 and 2 GHG Emissions

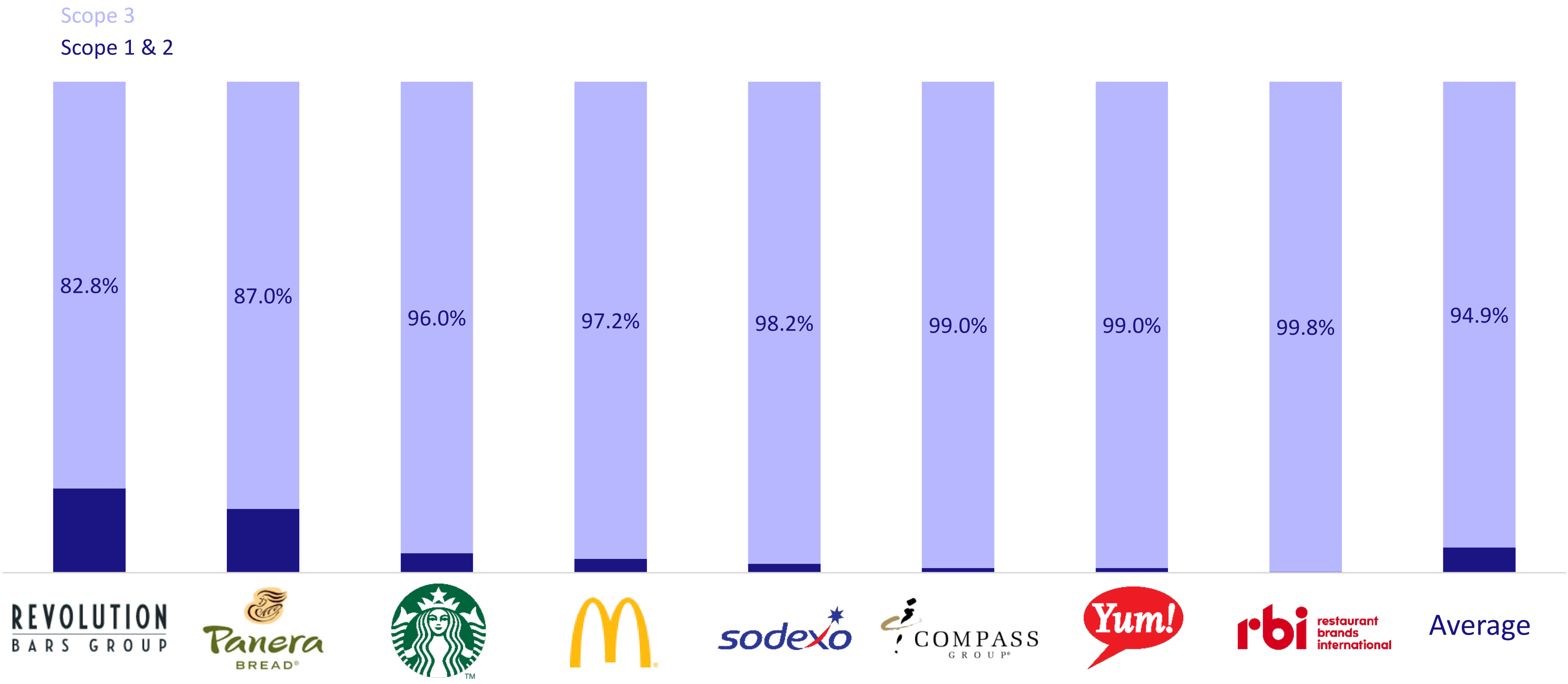
GHG protocol guidance and accounting for Scope 3 interventions, like regenerative agriculture, are still in development

Source: ISS ESG

Rabobank

Scope 3

…accounts for more than 90% of emissions for consumer food companies



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6 Strategies to Reduce Supply Chain Emissions

Alternative sourcing locations

Changing where materials are sourced for a lower GHG impact

Regenerative agriculture

Transitioning to a sustainable farming system that restores soil, encourages biodiversity, reduces GHG emissions

Product reformulation

Introducing new products or reformulating existing products using low-emission inputs

Innovation

Innovative inputs, such as methane-reducing feed additives, precision agriculture technologies and (plant-based) food innovation

Sustainable packaging

Reducing packaging or improving packaging's recyclability or biodegradability

Offsetting

Complementary nature climate solutions (NCS) within supply chains or through carbon credits to achieve net zero

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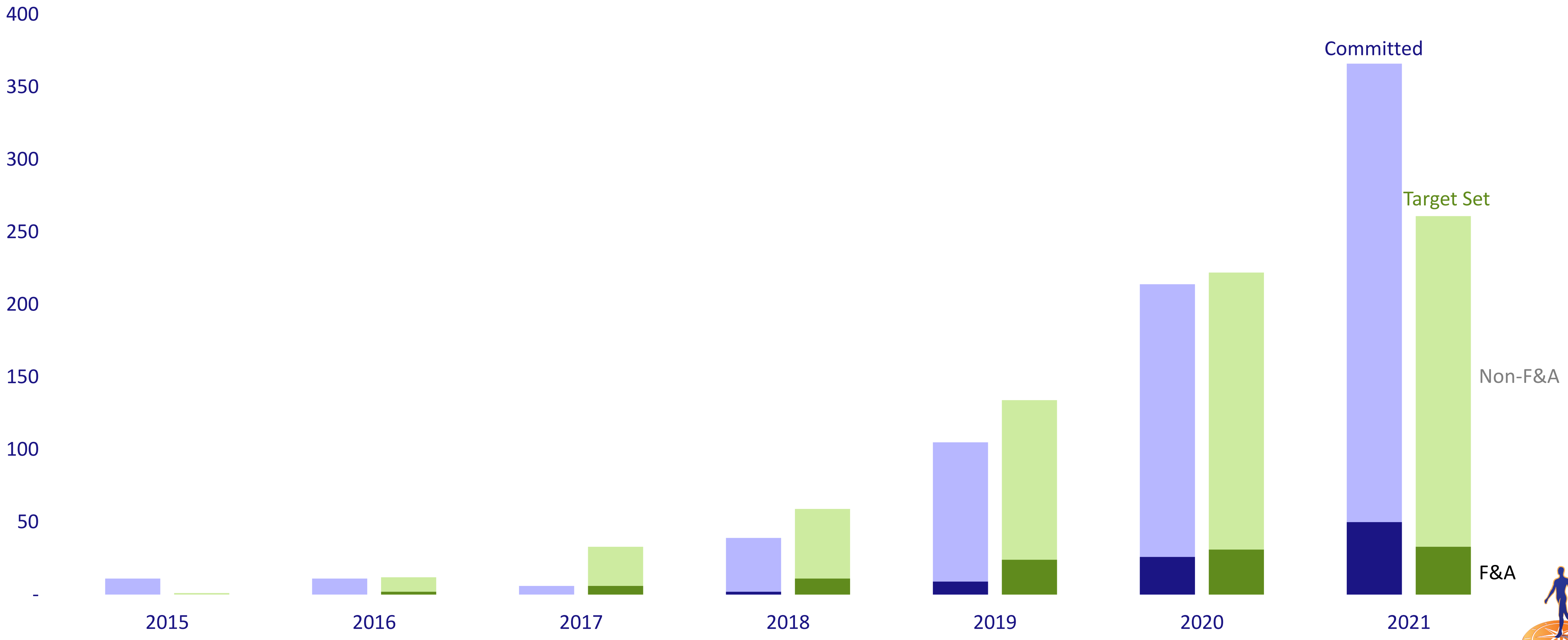
Scope 3 Target Setting



Source: Science Based Targets Initiative

Concluding Remarks

Where is this moving in the future?

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RESEARCH SUMMIT

SHAPING THE FUTURE OF SUSTAINABILITY IN ANIMAL AGRICULTURE

FIVE RIVERS

CATTLE FEEDING

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FOR ANIMAL AGRICULTURE

Looking toward the future : How do we build consensus and fill gaps?

Vision

Animal agriculture is a sustainable component of our global food system by providing economic, social and environmental benefits to Colorado, the Nation, and the world.

Mission

Identify and scale innovation that fosters the health of animals and ecosystems to promote profitable industries that support vibrant communities.

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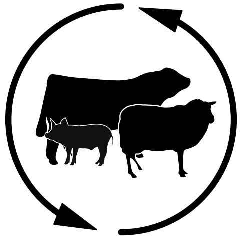
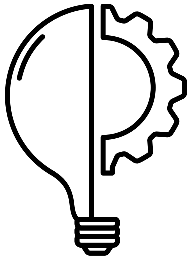
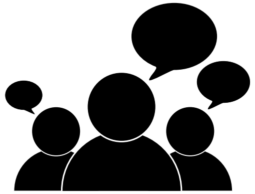
Purpose



Lead scientific discovery by pushing boundaries of what we know is possible



Innovate and implement best practices



Convene critical conversations

711 Ranch
James Henderson
CEO

Beatty Canyon Ranch
Steve Wooten
President, CEO

Beef Marketing Group
John Butler
CEO

Brackett Ranches
Kim Brackett
CEO

Five Rivers
Mike Thoren
President, CEO

Veterinary Research & Consulting, LLC
Tom Portillo
Partner

Harper Livestock
Mike Harper
President, CEO

JBS USA
Cameron Bruett
Head of Corporate Affairs and Chief Sustainability Officer

LeValley Ranches
Robbie LeValley
CFO

Kraft Family Dairies
Mary Kraft
CFO

Safeway/Albertsons
Cathy East
Vice President Procurement Meat/Seafood/Deli

Veterinary Research & Consulting, LLC
Del Miles
Founder

Phased Cluster Hires 2021-2025

- Population Health (2 positions)
  - Disease Epidemiologist
- Systems Modeling*
- Feedlot Specialist*
- Dairy Specialist*
- Rangeland Scientist
- Cow Calf Population Health Management Specialist

- Animal Agriculture Law and Policy Specialist
- Environmental Impact Scientist
- Emerging Agriculture Technology Scientist
- Grazing System Specialist
- Nutritional Epidemiologist
- Emerging Infectious Disease Specialist
- Livestock Economist*

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~$4.5M

Strategic Partnership

UNIVERSITY OF WYOMING

Colorado State University

TEXAS A&M AGRILIFE RESEARCH

UNIVERSITY OF ARKANSAS

USDA Agricultural Research Service

We will leverage talent, facilities, leadership, external funds and knowledge working alongside our industry partners to solve the worlds greatest challenges.

The Partnership for Real-World Sustainable Solutions in Beef Cattle Production

We Need Your Partnership

Quantify greenhouse gas emissions. Data from production environments is limited and novel strategies are needed to accurately benchmark.

Develop scalable solutions for methane mitigation. Solutions must be economically feasible and practically applicable for producers.

Identify opportunities for carbon sequestration and maintenance across the landscape. Solutions for carbon sequestration and maintenance in regionally diverse grazing landscapes that include social and economic aspects are needed.

Develop practical solutions to mitigate other greenhouse gas and atmospheric pollutants. Novel strategies to reduce reactive nitrogen and carbon dioxide are needed.

Quantify improvements over time. Appropriate benchmarking, tracking improvements, and developing scenarios to predict transformational change is needed.

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~$4.5M

Opportunities

Quantify greenhouse gas emissions. Accurate benchmarking and novel measurement strategies to more credibly document and understand emissions from cattle in their natural environments.

Develop scalable solutions for methane mitigation. Genetic selection, feed additives, technology, vaccines, with evaluation across sectors.

Identify opportunities for carbon sequestration and maintenance across the landscape. Matching grazing with forage growth, integrated livestock grazing cropping systems, linking heterogeneity and biodiversity outcomes in arid and semi-arid rangelands, precision herding combined with remote sensing and daily biomass metrics, and matching genetics to the environment.

Develop practical solutions to mitigate other greenhouse gas and atmospheric pollutants. Enhanced manure management, monitoring, and land application, manure-derived renewable fuels, displacing fossil fuels, nitrous oxide mitigation, and state frameworks for cost recovery.

Quantify improvements over time. Data base management, model improvement and iteration to ensure appropriate benchmarking and tracking of progress.

Infrastructure

- Most significant gap that we have is in infrastructure
- Leverage facilities
  - Texas Tech with Dr. Hales "fail fast and cheap" focused on innovation
  - CSU takes innovation with promise and evaluates scalability
- Extend network across a variety of landscapes to understand complexities, regional differences
  - Network of partner ranches to evaluate landscape differences and commonalities
  - Network of research and partner feedyards to evaluate system level performance
- Work back to a common metrics to measure and track progress
- Multi-disciplinary team with industry input and collaboration to identify scalable solutions

Respiration Chambers

- Test methane mitigation strategies
  - Extremely accurate and precise
- Whole animal nitrogen balance
  - Complete urine and fecal collections
- Energetics

~$300,000

Complete Nutrient Monitoring Pens

- Pen level mass balance pens
  - Measure N emissions as the residual of N intake and N from scrapped pen
- Individual animal enteric methane emission on a producer relevant scale
- Test dietary interventions, pen applications, and individual animal (genetics, health status, implant strategy, etc.).
  - How does stress or morbidity in one sector impact emissions and performance in the finishing phase?
- Complete life cycle monitoring to understand tradeoffs of management decisions in different sectors and its downstream impacts on performance and emissions
- Use the facility to improve the ability to measure pen level emissions and improve estimation of uncertainty in emissions
- ~$600,000

Quantification and Tracking Progress

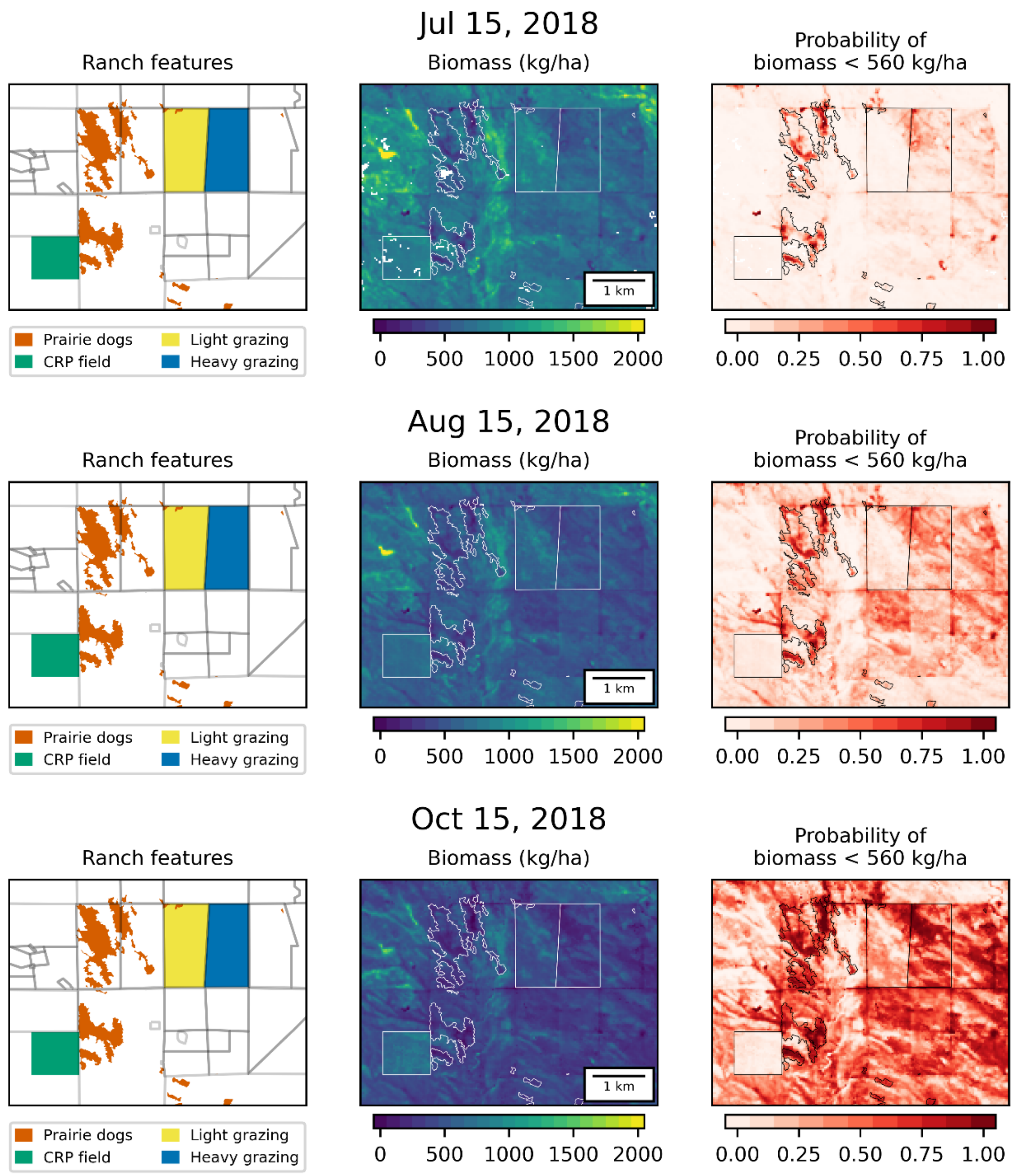
Quantify greenhouse gas emissions:

- Inventories lack accurate data “enteric methane is a black hole”
  - Strategies listed above will help
- Concentrated effort in grazing animals, emissions change daily based on diet, incredible variability in season and animal

Quantify improvements over time.

- IT infrastructure to track progress at scale
- Inclusive of data collection and data reduction

~$1M


Jul 15, 2018
Ranch features
Biomass (kg/ha)
Probability of biomass < 560 kg/ha
1 km
Prairie dogs
Light grazing
CRP field
Heavy grazing
0 500 1000 1500 2000
0.00 0.25 0.50 0.75 1.00
Aug 15, 2018
Ranch features
Biomass (kg/ha)
Probability of biomass < 560 kg/ha
1 km
Prairie dogs
Light grazing
CRP field
Heavy grazing
0 500 1000 1500 2000
0.00 0.25 0.50 0.75 1.00
Oct 15, 2018
Ranch features
Biomass (kg/ha)
Probability of biomass < 560 kg/ha
1 km
Prairie dogs
Light grazing
CRP field
Heavy grazing
0 500 1000 1500 2000
0.00 0.25 0.50 0.75 1.00

~$500,000

Continual Measurement

Circular source area geometry to measure continuously. Compare management strategies at scale.

~$2M

The Partnership for Real-World Sustainable Solutions in Beef Cattle Production

We Need Your Partnership

AgNext needs your support for infrastructure, identifying robust baseline measurements, and developing scalable solutions. **Our initial ask is to raise $2.5M on our way to $4.5M.**

Any contribution is significant and welcome.

For organizations that feel fully committed to what we are focused on and will accomplish we are offering a more formal and long-term option:

Principal Partner: Annual Commitment of $100,000

Partner: Annual Commitment of $50,000

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Thank you

@CSUAgNext

AgNext at Colorado State University

@CSUAgNext

Kim.Stackhouse-lawson@colostate.edu

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