DECREASING THE SLOVAK DAIRY SECTOR'S METHANE FOOTPRINT FOR A THRIVING ECONOMY

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https://www.animalgeneticresources.net/index.php/country/slovakia/

Outline

1. Setting the Stage: Global food, livestock, and dairy systems emissions & targets
2. It's not the **Cow**, it's the **How**: Greenhouse gas (GHG) emissions mitigation opportunities in the Slovak dairy sector
3. Policy & Partnerships: Leveraging public-private partnerships to achieve sustainable dairy production
4. Feeding & Educating the Next Generation for a Sustainable Future

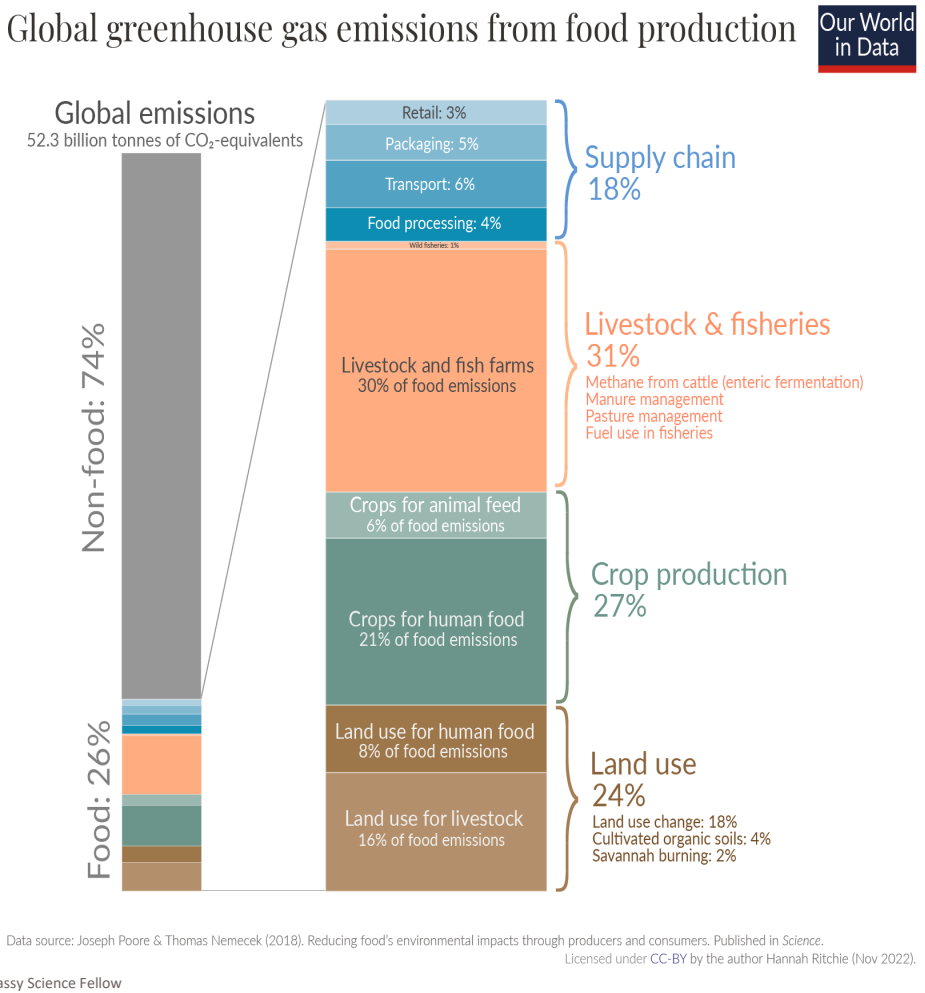
Global livestock, and dairy systems GHG emissions

Slovakia Greenhouse Gas (GHG) Emissions Targets

- Commitment to carbon neutrality by 2050
- Goal to reduce GHG emissions by 20% by 2030 (Greener Slovakia)
- Average per capita GHG emissions < EU average
- Decoupling of GHG emissions and economic performance
- Agriculture accounted for only 7% of Slovakian GHG emissions in 2019
  - Agricultural emissions: **76.3%** of methane and 90% of nitrous oxide

Global Food System GHG Emissions

- Breakdown of emissions from food production
- Greenhouse gases: CO_2, CH_4, NO_2
- Not all gases behave the same!
- 14% of global GHG emissions attributed to animal agriculture
- Focus on **methane**



Methane (CH_4) v. Carbon Dioxide (CO_2)

Methane

- Short atmospheric lifespan
- ~17% of global GHG emissions from human activities
- **GWP100: 28-36**
- Main sources of emissions:
  - **Animal agriculture**
  - Fracking & transportation
  - Landfills

Carbon Dioxide

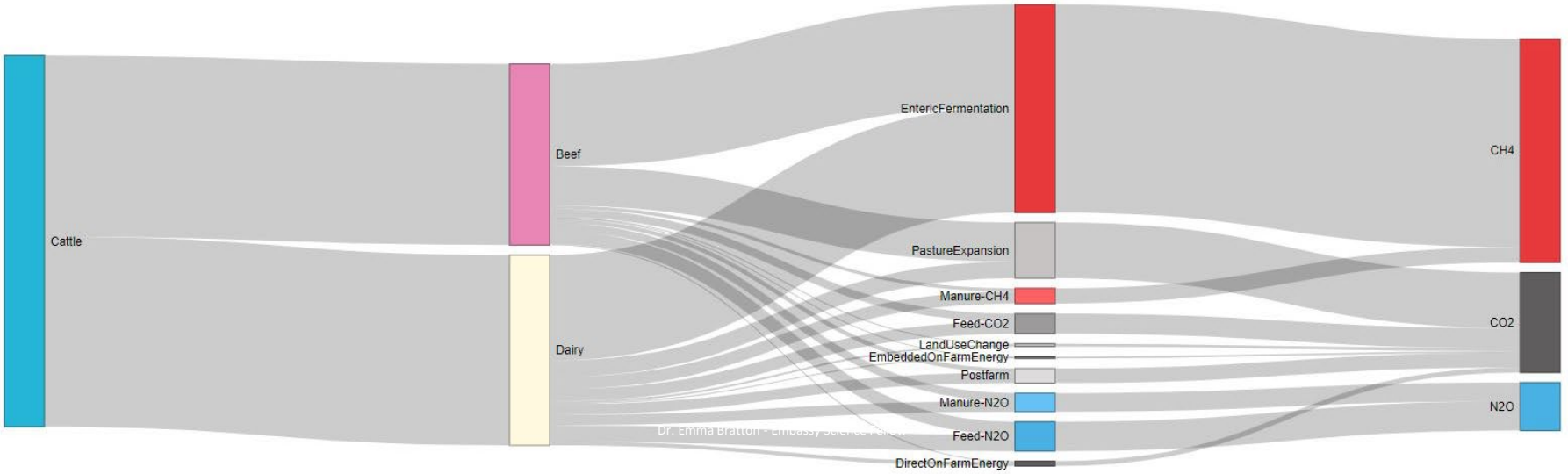
- Long atmospheric lifespan
- ~76% of global GHG emissions
- GWP100: 1
- Main sources of emissions:
  - Electricity & heat
  - Transportation
  - Manufacturing & construction

Methane Emissions Targets – Global Methane Pledge

- Voluntary commitment by >150 partner countries, including **Slovakia**
- Potential to avoid **>0.2˚C of warming by 2050**
- **Commitments:**
  - Reduce methane emissions from all sectors by at least 30% below 2020 levels by 2030
  - Abatement of agricultural emissions via technology & innovation
  - Policy transparency & annual reporting
  - Highest tier IPCC good practice inventory methodologies
  - Support existing international methane emissions reduction initiatives

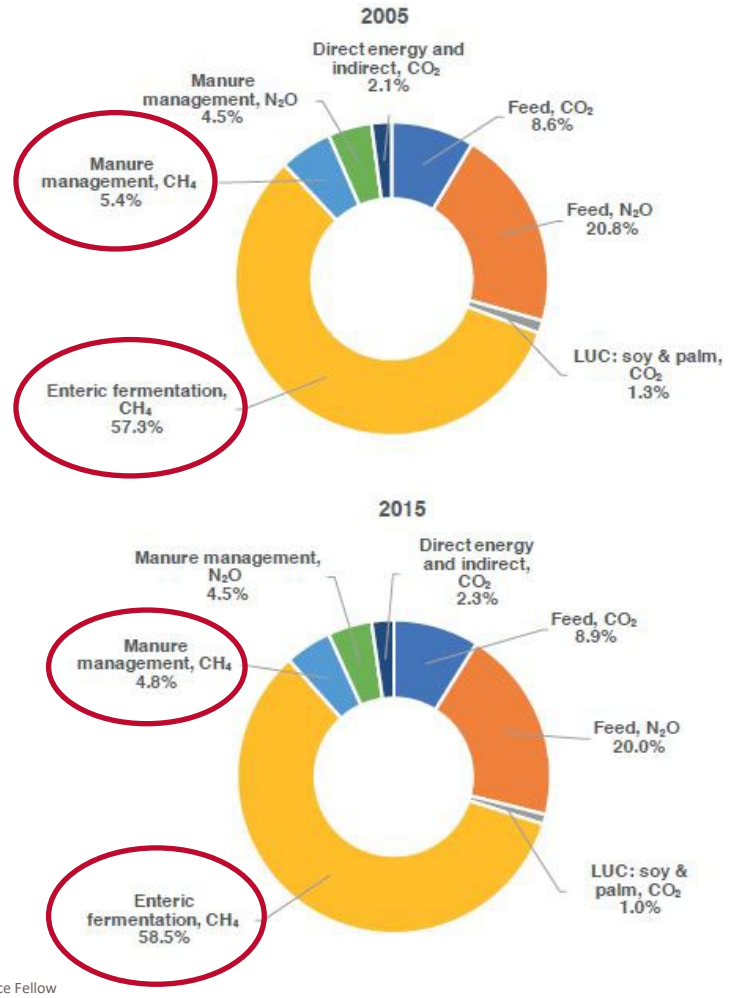
Global Dairy Methane Emissions – GLEAM Data

- Total global dairy cattle methane emissions – 1,246.746 Million tonnes CO_2eq
- Methane missions from enteric fermentation – 1,088.310 M tCO_2eq
- Methane emissions from manure – 158.436 M tCO_2eq



Global Dairy Emissions – FAO Data

- Proportion of methane emissions is large & rising (62.7% to 63.3%)
- Proportion from enteric fermentation is large & rising (57.3% to 58.5%)
- **Reducing methane emissions from enteric fermentation is key to dairy sector GHG emissions mitigation**



It's not the **Cow**, it's the **How**: GHG emissions mitigation opportunities in the Slovak dairy sector

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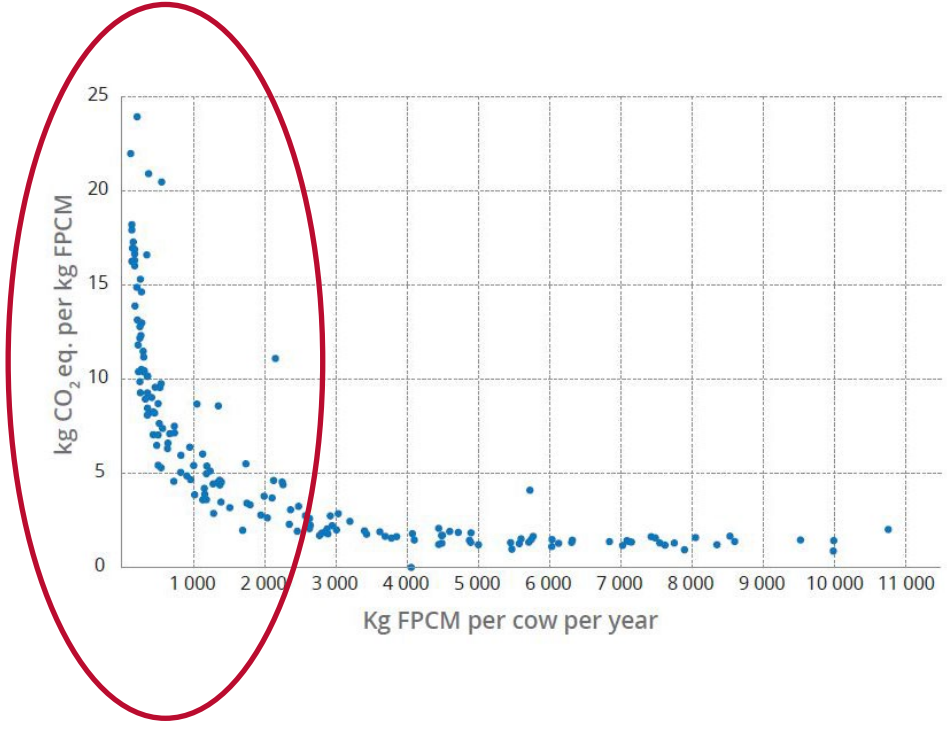
Slovakian Dairy Sector – On Farm

- Farm size & type
- Dairy production & trends
  - Milk yield
  - Age at first calving (AFC)
  - Productive lifespan

GHG Emissions Intensity

- Kg CO_2 eq / unit of food produced
- **Decreased intensity with increased efficiency**
- Mitigation potential for systems that produce <2000 kg FPCM/year
- Evidence-based targeting & managing trade-offs



FAO, Five practical actions towards low-carbon livestock, 2019

“Triple-Win” Scenario

- Economic growth
- Methane emissions reduction
- Improved nutrition

https://www.heinens.com/stories/we-know-our-sources-mayfield

Mitigating Dairy's Environmental Footprint

Estimated GHG contribution of each "print" to the total*:

Feed (26%) | Enteric (35%) | Manure (33%) | Energy (6%)

ENTERIC METHANE 35%

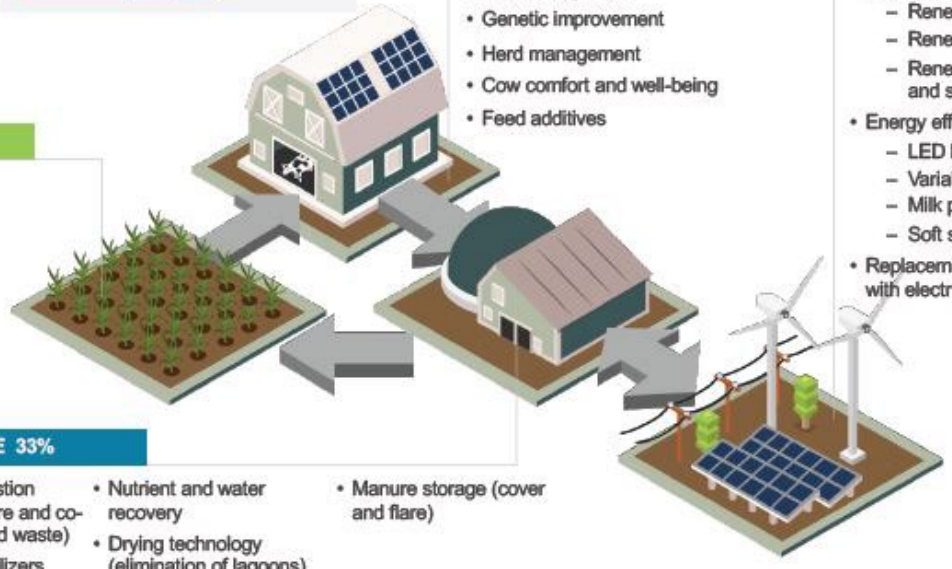
- Diet management
- Genetic improvement
- Herd management
- Cow comfort and well-being
- Feed additives

ENERGY 6%

- Renewable energy:
  - Renewable electricity
  - Renewable natural gas
  - Renewable energy from wind and solar sources
- Energy efficiency:
  - LED lighting
  - Variable speed pumps
  - Milk pre-cooling technology
  - Soft start motors
- Replacement of fossil-fueled engines with electric motors

FEED 26%

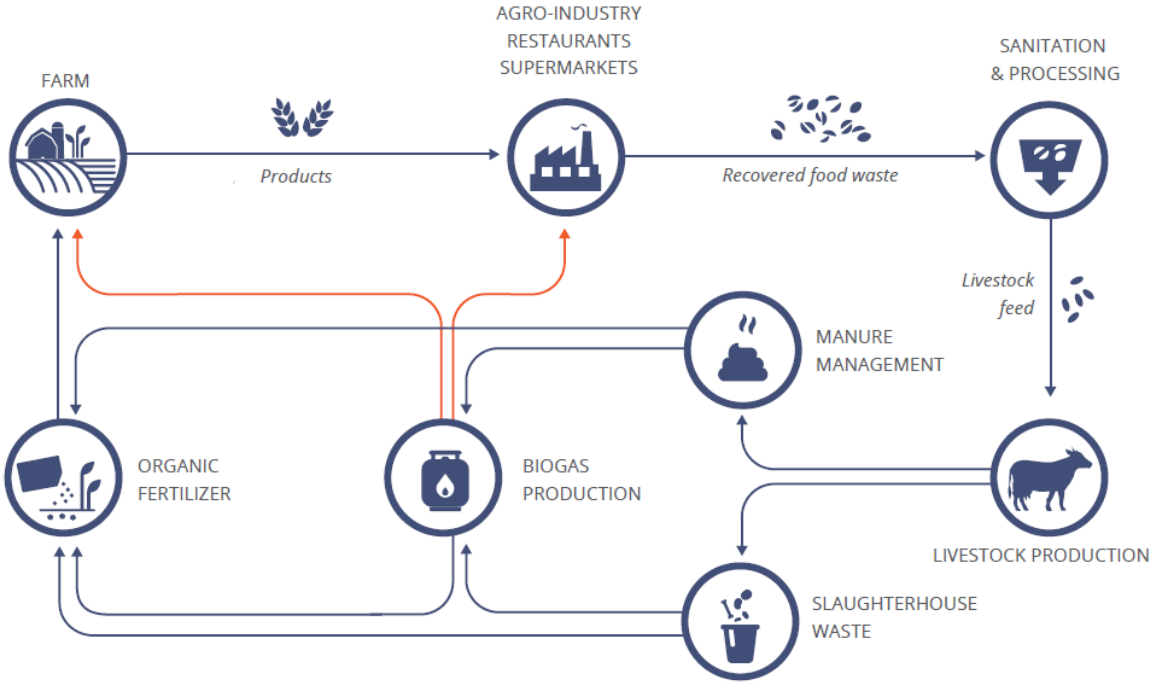
- No/low-till farming
- Cover crops
- Nutrient management
- Precision agriculture
- Water use efficiency



MANURE 33%

- Anaerobic digestion (includes manure and co-digestion of food waste)
- Renewable fertilizers
- Nutrient and water recovery
- Drying technology (elimination of lagoons)
- Manure storage (cover and flare)

Circular Bioeconomy



FAO, Five practical actions towards low-carbon livestock, 2019

Dairy Methane Emissions Mitigation Principles

1. Increasing dairy production efficiency to decrease methane emissions intensity
2. Altering manure management systems
3. Increasing circularity & carbon sinks

Strategies for Decreased Dairy Methane Emissions

Animal production efficiency

1. Optimize diet formulations
2. Optimize breeding systems
3. Improve information and technology integration & spread
4. Set up or integrate market systems
5. Improve animal health and biosecurity

Strategies for Decreased Dairy Methane Emissions

Manure management

1. Anaerobic digestion
2. Composting

Strategies for Decreased Dairy Methane Emissions

Circular Bioeconomy & Carbon Sinks

1. Grazing management
2. Integrated crop-livestock systems
3. Agroforestry & silvopastoral systems
4. Minimizing on-farm & off-farm losses

Optimized Diet Formulations – GFARP

- Global Farm Animals Ration Programs - Vietnam
- Locally-relevant and easily accessible information
- Economically & environmentally efficient
- Feed additives, e.g. Bovaer

Optimized Breeding Systems

- Calving interval
- Estrus detection
- Artificial insemination (AI)
- Embryo transfer (ET)

Category	Species	Relative effectiveness	Input required to achieve desired effect
Genomic selection for fertility	All ruminants and swine	Medium	High
Artificial insemination	All ruminants and swine	High	Moderate or high
Hormonal synchronization	All ruminants and swine	Medium	High
Embryo transfer	All ruminants and swine	High	High

Hristov et al. 2013a

Improved Technology & Information Integration - DigiCow Dairy

- Heifer International
- Trainings & community knowledge
- Animal husbandry
- Veterinary services

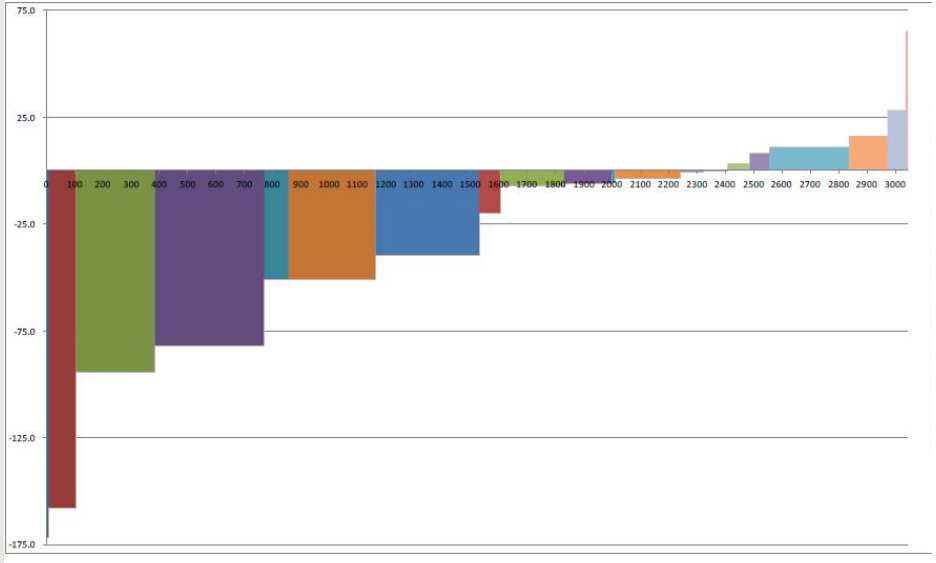
Heifer International; Russel Powell

Integrated Market Systems – KCDMS Activity

- Began in 2017
- Market linkages, improved breeding & animal health, extension services, better input access
- Interventions
- Results:
  - **Productivity** increased by an average of **43%**
  - **Methane emissions intensity** decreased by an average of **27%**

Improved Animal Health & Biosecurity

- Life Cycle Analyses (LCA)
- Marginal Abatement Cost Curves (MACC)
- Low cost, high reward



Study to Model the Impact of Controlling Endemic Cattle Diseases and Conditions on National Cattle Productivity, Agricultural Performance and GHG Emissions, Feb. 2015

Animal Health, Welfare, and Sustainability

- EU Farm to Fork, UN, World Organization for Animal Health (OIE)
- Freedom from pain injury, and disease
- Animal welfare indicators included in sustainability assessments
- Sustainable intensification tradeoffs & mitigation strategies

Anaerobic Digestion – Chase Goodrich

- Dairy Farm in Vermont, USA
- ~5 M liter anaerobic digester
- Local community connection
- Overhead: digester staff & costs

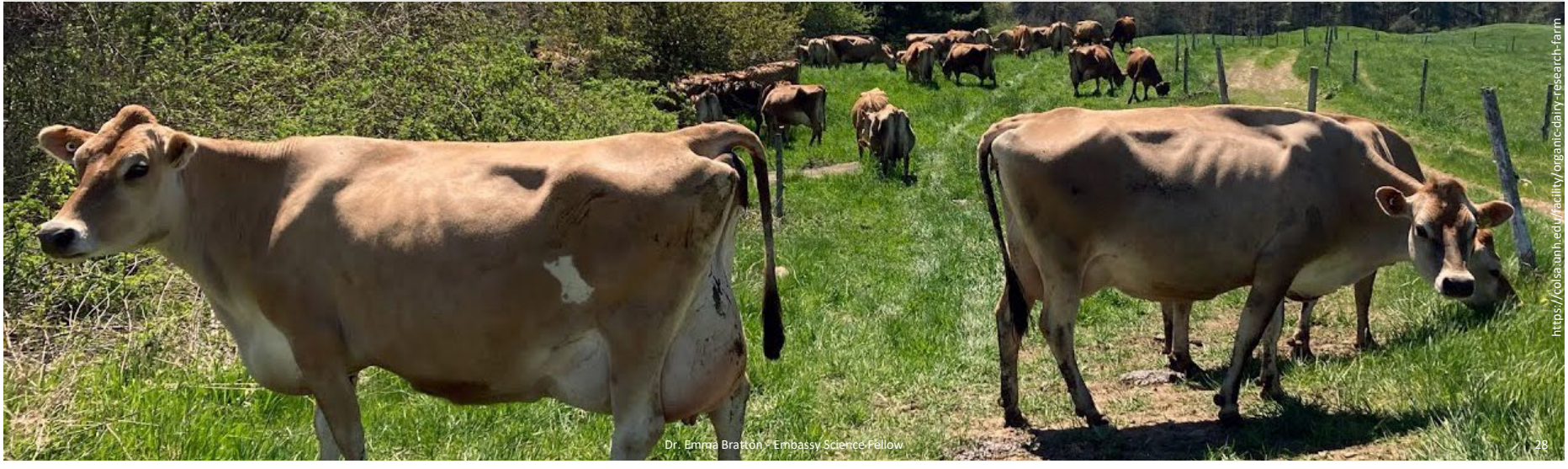
Manure Composting – Suzanne Vold

- Dairy Farm in Minnesota, USA
- Daritech "Bedding Master" compost drum
- Converts cow manure into bacteria-free dry bedding in 24 hours

https://www.usdairy.com/news-articles/farmers-reducing-methane-gas-from-cows

Grazing Management – UNH ODRF

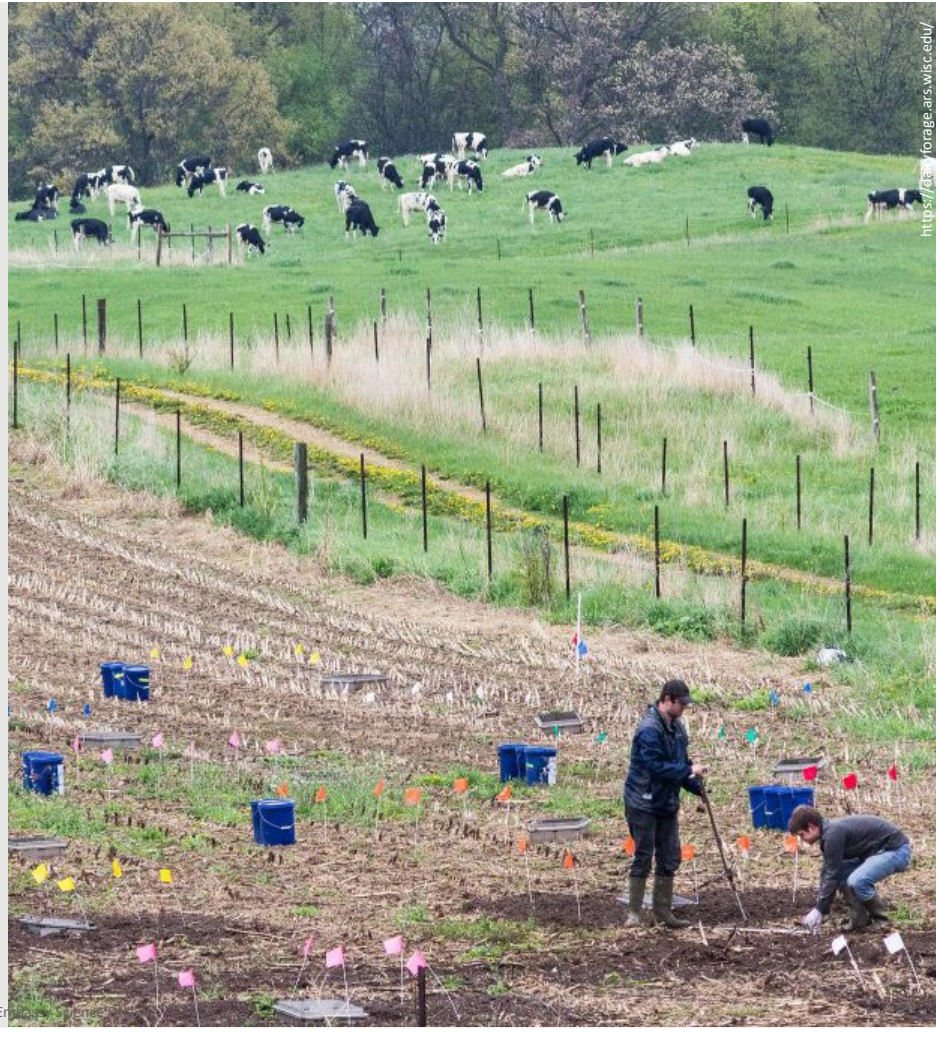
- Organic Dairy Research Farm—University of New Hampshire, USA
- 79 Jersey cows on 40 hectares of certified organic pasture
- MIG grazing can increase soil carbon by 3.2 g/kg
- Initial soil carbon content matters!



https://colsa.unh.edu/facility/organic-dairy-research-farm

Integrated Crop-Livestock Systems – University of Wisconsin, USA

- Dairy Forage Research Center (DFRC) – University of WI, Madison, USA
- 400 dairy cows
- Forest, shrubs, forage crops, pasture, grass
- Nearly neg. 20 M kg CO_2 eq net GHG emissions
- Alfalfa is key!
- Sustainable agroecological system



Agroforestry Systems – Tim Downes

- Significant soil carbon sequestration
- Native trees improve animal & soil health
- Adequate precipitation – 1 m/year

Dr. Emma Bratton - Embassy Science Fellow

https://www.reuters.com/business/sustainable-business/how-agroforestry-can-help-turn-cows-climate-criminals-into-heroes-2022-11-08/

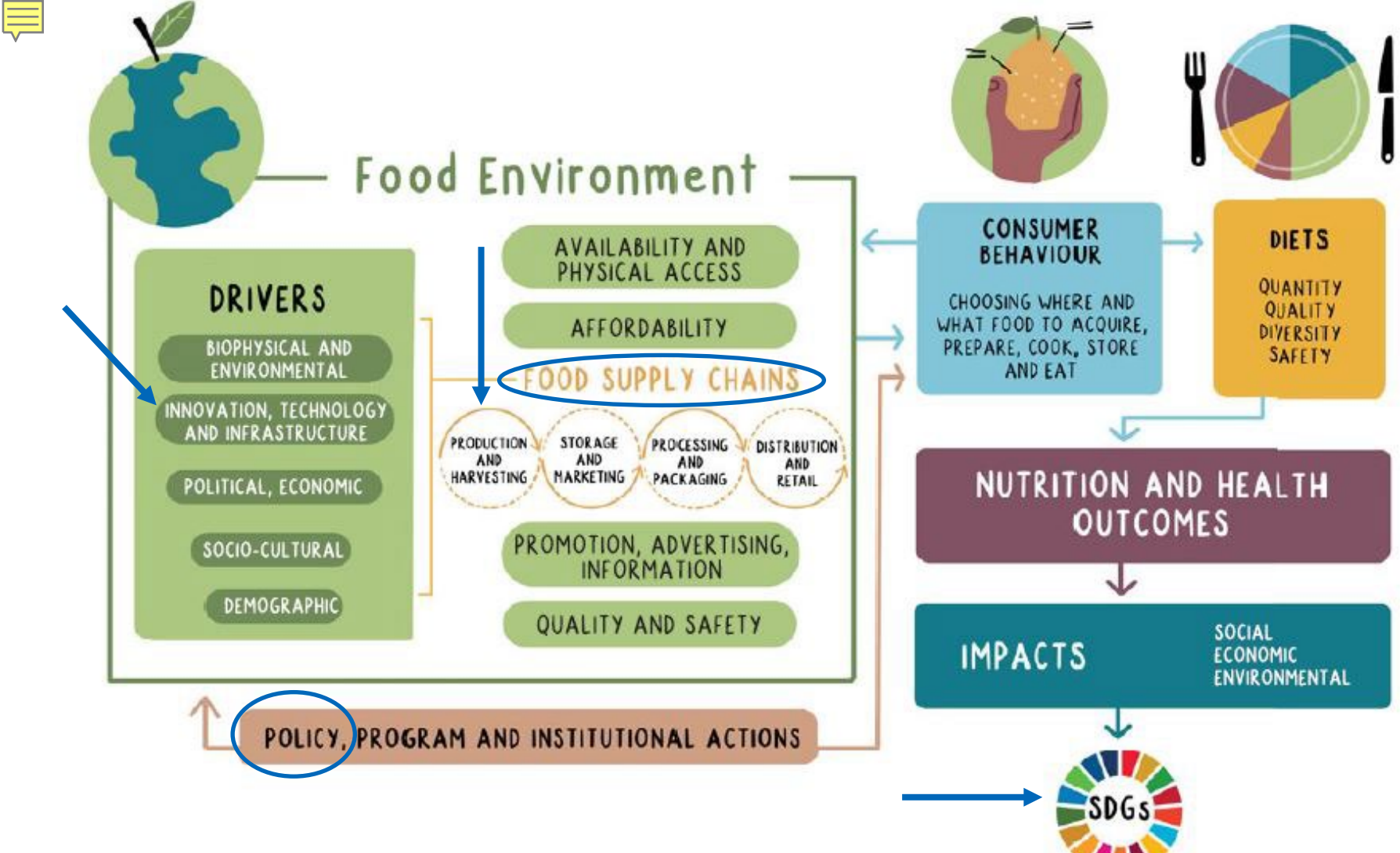
Minimizing Food Loss & Waste – Bangladesh LAN Activity

- Feed the Future Bangladesh Livestock & Nutrition Activity
- USAID & ACDI/VOCA
- Byproducts → commodities
- Sanitation & storage
- Labeling & bioprotective cultures

https://agrilinks.org/post/reducing-food-loss-lessons-bangladeshs-dairy-sector

Summary – Dairy Methane Mitigation Strategies

- **Decreasing methane emissions intensity and capturing methane emissions**
- Increasing on-farm productivity & strengthening market linkages
- Manure storage, processing and biogas generation
- Capturing carbon via grazing, agroforestry, and integrated crop-livestock systems


Food Environment
DRIVERS
BIOPHYSICAL AND ENVIRONMENTAL
INNOVATION, TECHNOLOGY AND INFRASTRUCTURE
POLITICAL, ECONOMIC
SOCIO-CULTURAL
DEMOGRAPHIC
AVAILABILITY AND PHYSICAL ACCESS
AFFORDABILITY
FOOD SUPPLY CHAINS
PRODUCTION AND HARVESTING
STORAGE AND MARKETING
PROCESSING AND PACKAGING
DISTRIBUTION AND RETAIL
PROMOTION, ADVERTISING, INFORMATION
QUALITY AND SAFETY
CONSUMER BEHAVIOUR
CHOOSING WHERE AND WHAT FOOD TO ACQUIRE, PREPARE, COOK, STORE AND EAT
DIETS
QUANTITY
QUALITY
DIVERSITY
SAFETY
NUTRITION AND HEALTH OUTCOMES
IMPACTS
SOCIAL
ECONOMIC
ENVIRONMENTAL
POLICY, PROGRAM AND INSTITUTIONAL ACTIONS
SDGs

Public-Private Partnerships to Achieve Sustainable Dairy Production

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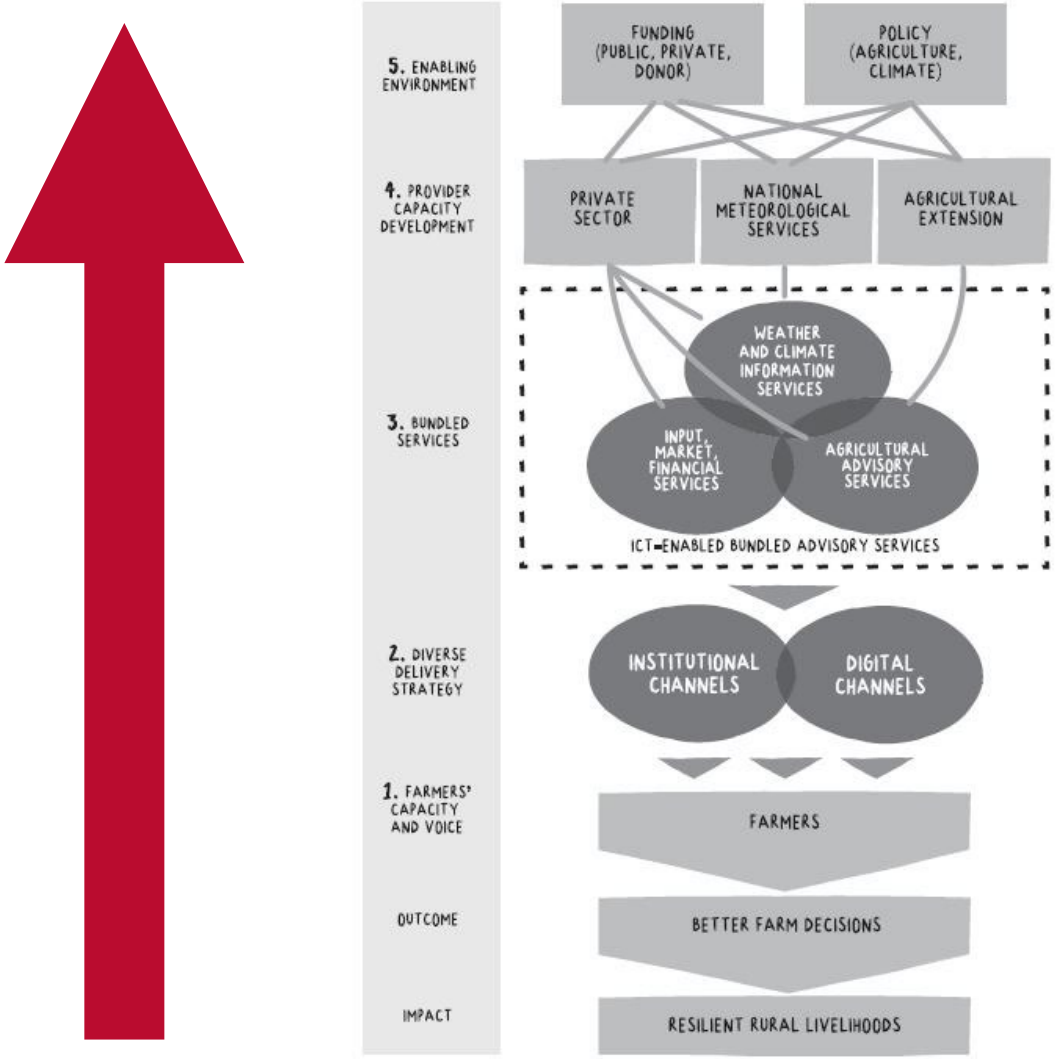

5. ENABLING ENVIRONMENT
FUNDING (PUBLIC, PRIVATE, DONOR)
POLICY (AGRICULTURE, CLIMATE)
4. PROVIDER CAPACITY DEVELOPMENT
PRIVATE SECTOR
NATIONAL METEOROLOGICAL SERVICES
AGRICULTURAL EXTENSION
3. BUNDLED SERVICES
WEATHER AND CLIMATE INFORMATION SERVICES
INPUT, MARKET, FINANCIAL SERVICES
AGRICULTURAL ADVISORY SERVICES
ICT-ENABLED BUNDLED ADVISORY SERVICES
2. DIVERSE DELIVERY STRATEGY
INSTITUTIONAL CHANNELS
DIGITAL CHANNELS
1. FARMERS' CAPACITY AND VOICE
FARMERS
OUTCOME
BETTER FARM DECISIONS
IMPACT
RESILIENT RURAL LIVELIHOODS

Climate Finance

- Leveraging multiple funding sources—domestic & international
- Bundling financial instruments
- Incentives & disincentives
- Carbon/methane markets
- **Public-private partnerships**

Climate Finance – Funding Sources & Instruments

Sources

- Multilateral
  - **Green Climate Fund**
  - World Bank
  - Global Environment Facility
- Domestic
  - **"Climate Fund for Soil"**
  - National banks

Instruments

- Carbon markets
  - EU Emissions Trading System (ETS)
- Carbon/methane tax
- Subsidies
- Loans

Partnerships for Climate-Smart Commodities

- $3.125 billion in 141 projects
- Project approaches (broad):
  - Technical & financial assistance
  - GHG data collection
  - Market development
- Anticipated results:
  - >60K farmers & >10 M hectares of land
  - Nearly 100 universities
- Dairy Farmers of America (DFA) dairy methane project

USAID Climate Strategy 2022-2030 Strategic Framework

SO 1. TARGETED DIRECT ACTION

Accelerate and scale targeted climate actions

IR 1.1 Reduce Emissions

Catalyze urgent mitigation (emissions reductions and sequestration) from energy, land use, and other key sources

IR 1.2 Build Resilience

Strengthen resilience of populations vulnerable to climate impacts (adaptation)

IR 1.3 Mobilize Finance

Increase the flow of and equitable access to finance to support adaptation and mitigation

IR 1.4 Partner with IPLCs

Partner with Indigenous Peoples and local communities to lead climate actions

IR 1.5 Amplify Crucial Voices

Enable and empower women and youth and other marginalized and/or underrepresented groups to lead climate action

Embedded Principles

- Locally Led Development
- Equity and Inclusion
- Private-Sector Engagement
- Nature-Based Solutions
- Evidence and Innovation

SO 2. SYSTEMS CHANGE

Catalyze transformative shifts to net-zero and climate-resilient pathways

IR 2.1 Transform Key Systems

Advance transformation of key systems and essential services to reduce emissions and enhance climate resilience

IR 2.2 Shift Market Signals

Support a transition to resilient, net-zero economies and financial systems

IR 2.3 Improve Governance

Strengthen responsive, transparent governance and citizen engagement for effective climate action

IR 2.4 Work Across Assistance Types

Strengthen the coordination of humanitarian, development, and peacebuilding assistance to address climate impacts

SpO 3. DO OUR PART

Strengthen the operations and approaches to programming to address climate change and further climate justice within USAID and our partner organizations

EU Farm to Fork Policy

Key Principles

- Healthy, affordable, sustainable food
- Tackle climate change
- Protect the environment & preserve biodiversity
- Fair economic return in the food chain
- Increase organic farming

Quantitative Goals - by 2030

- Reduce the use of **pesticides** by **50%**
- Reduce **soil nutrient losses** by at least **50%**
- Reduce **fertilizer** use by **20%**
- Reduce sale of **antimicrobials for farmed animals** by **50%**
- **25%** of total farmland is **organic**
- Reduce per capita **food waste** by **50%**

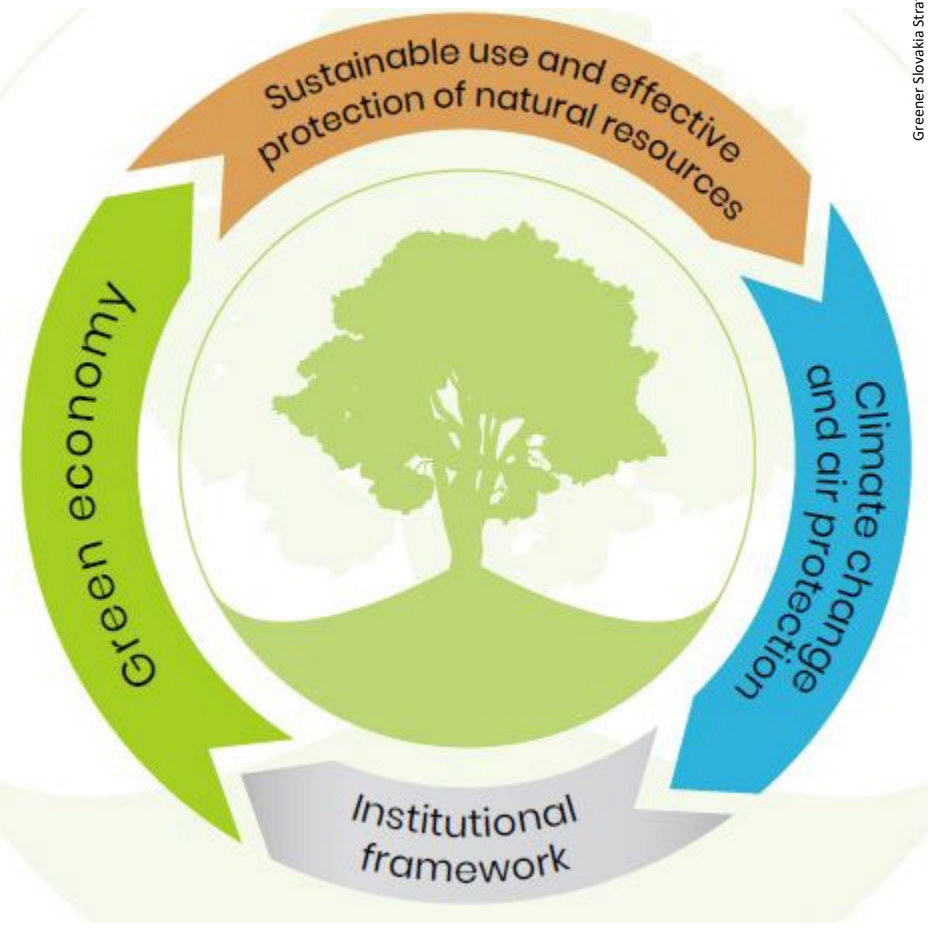
Greener Slovakia Strategy – Principles

Principles

- Natural resource management
- Climate change mitigation & adaptation and air quality protection
- Green/circular economy

Keys to Success

- The importance of data
- Leveraging public & private funds
- Multistakeholder cooperation



Greener Slovakia Strategy

Slovakian Agricultural Efficiency Opportunities

- Agricultural production diversity improves technical efficiency
- Optimize CAP subsidies to improve technical efficiency & decrease admin burden
- Increase farmer association membership to improve livestock production efficiency

Slovakian Dairy Sector Challenges & Opportunities

Challenges

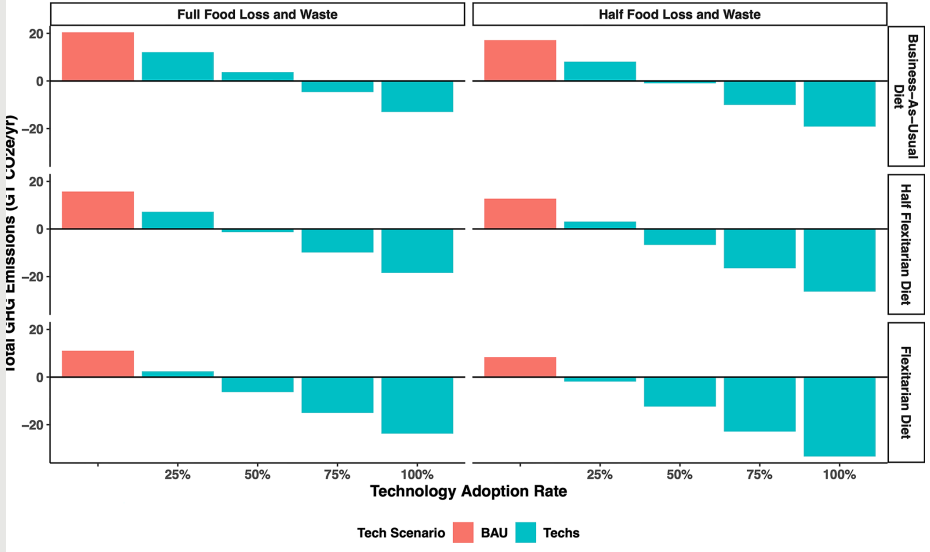
- Production efficiency
- Shrinking & aging workforce
- Lack of optimization of AKIS
- Ambitious climate targets
- Lack of coordination among stakeholders
- Lack of integration w/EU research infrastructure

Opportunities

- Improved production efficiency—small and large farms
- Improved coordination of research & technology development & uptake—Slovakia & EU
- Optimizing existing knowledge systems (AKIS)
- Enabling environment to support climate-smart agricultural technology

Improved Technology & Information Integration

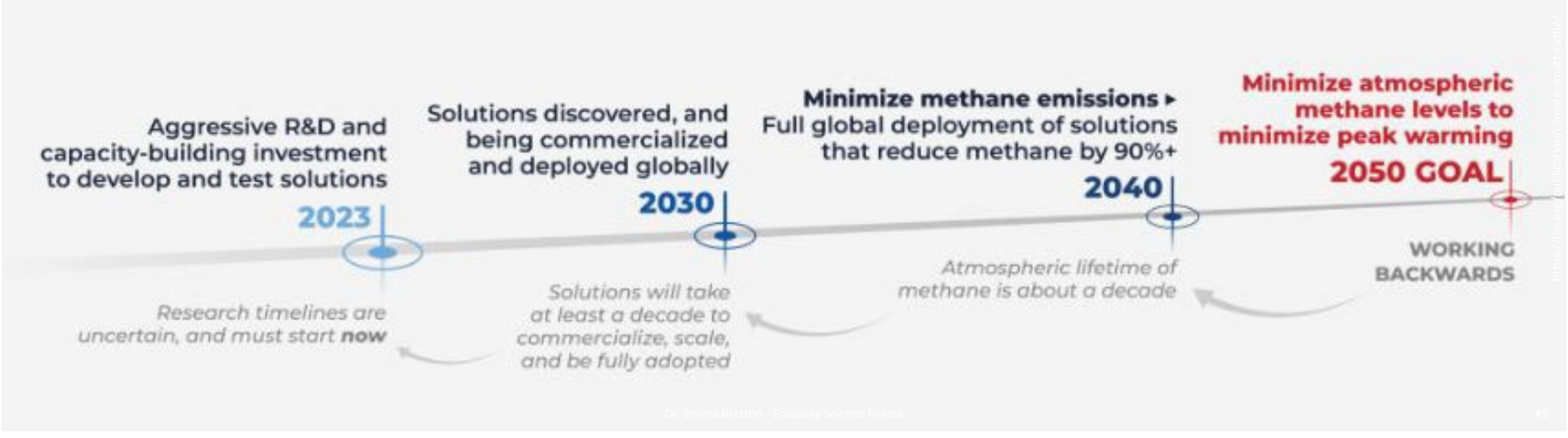
- Climate-smart agricultural technology has revolutionary potential
- Manure digestion – 79%
- Agroforestry – 26.42 tonnes CO_2/ha
- Digestible forage – 35%
- Feed additives – 46%
- **Scalability & cost**



Almaraz et al. 2023

Mapping Research Priorities

- Direct funding & policy action with specific financial & time-based goals
- Five action steps for policymakers
- Leveraging existing policy & funding mechanisms



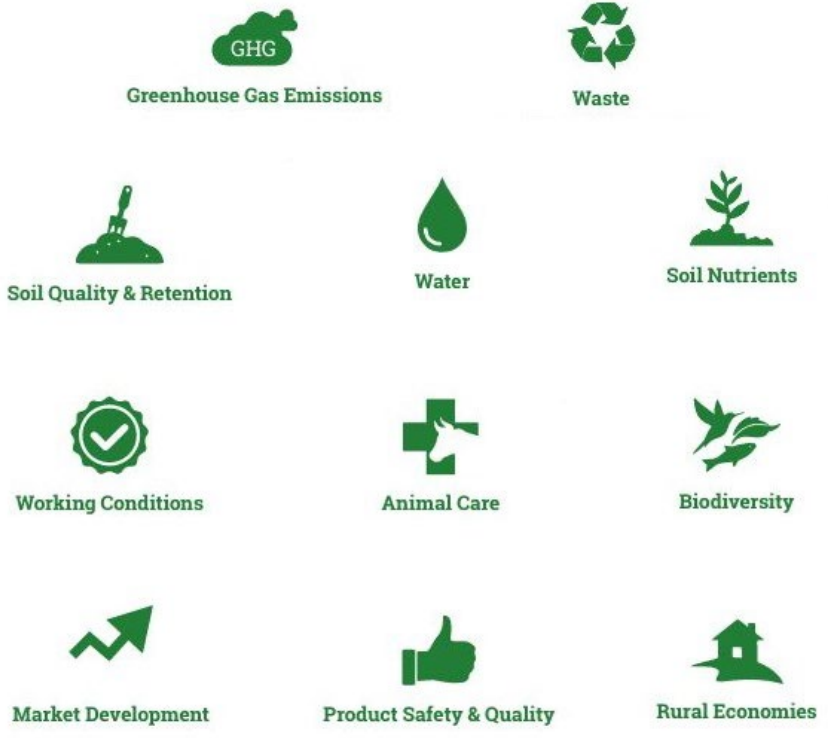
The Importance of Data

Measurement – Cool Farm Tool

- **GHG emissions, water use, and biodiversity**
- Quantitative, credible, and standardized metrics
- Connects management decisions to environmental effects
- Creates "what-if" scenarios and simulates GHG emissions effects
- Adopted and tested by multinational companies, e.g. Bel group
- Water—70% fresh water used by agriculture globally
  - Minimal data entry, maximum output
- Biodiversity—quantitative score that builds over time
  - Wide array of species and management practices included

Dairy Sustainability Framework (DSF)

- Continuous sustainability improvement of the global dairy sector
- 11 environmental, social, and economic sustainability criteria
- Benefits of high-level indicators
- Benefits of DSF membership



https://fas.org/publication/climate-smart-cattle/

US Dairy Net Zero Initiative

- **Goal:** US Dairy achieves GHG emissions neutrality by **2050**
- Informed by & designed for US dairy producers
- Private sector-led

INNOVATION CENTER FOR U.S. DAIRY
HEALTHY PEOPLE • HEALTHY PRODUCTS • HEALTHY PLANET

DMI DAIRY MANAGEMENT INC.

IDFA International Dairy Foods Association

NEWTRIENT

NMPF NATIONAL MILK PRODUCERS FEDERATION

USA U.S. Dairy Export Council
Ingredients | Products | Global Markets

Partners and Collaborators

Nestlé

FFAR

https://www.usdairy.com/sustainability/environmental-sustainability/net-zero-initiative

US Dairy Net Zero Initiative

Research, Analysis & Modeling

- Fill data gaps, generate knowledge, improve models,
- Improved understanding of technologies & practices
- Improve on-farm tools

On-Farm Pilots

- Implementing best practices
- Market-based approaches
- Provide scale

Scale Adoption

- Broad, voluntary farmer adoption
- Sharing positive impacts to improve learning
- Supply chain demonstration projects
- Increase awareness

Summary: Operationalizing this in Slovakia

- Mobilizing climate funds
- Public-private partnerships
- Multisectoral policy framework
- Technology & information dissemination
- Mapping research priorities
- The importance of data
- US DNZ – pulling it all together

Feeding & Educating the Next Generation for a Sustainable Future

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Vision for the Future – Dairy Farmers

- Integrating information on novel farming technologies and approaches
- Increased political engagement
- Circular bioeconomy
- Increased market linkages

Vision for the Future – Dairy Industry Stakeholders

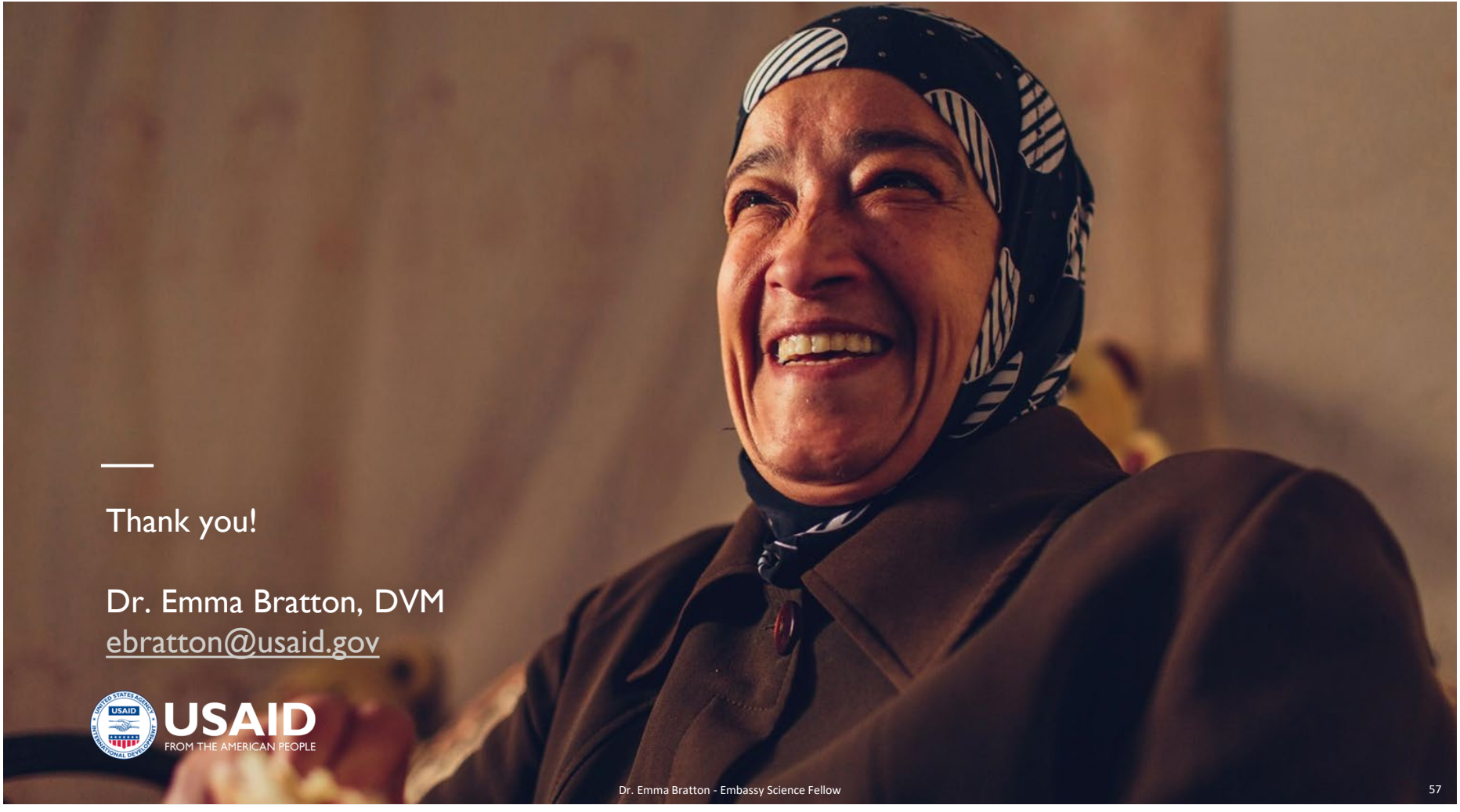
- Capitalizing on climate incentives
- Food systems perspective
- Balancing policy and consumer pressures

Vision for the Future – Veterinary & Agricultural Science

- "Whole farm" approach to animal science
- One Health/One Welfare approach
- Environmental and economic consulting

Vision for the Future – Agricultural Policymakers

- Mobilizing climate funds
- Creating a sustainable dairy production enabling environment
- Leveraging private sector partnerships
- Supporting robust data collection & information dissemination



Thank you!

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References

1. ADAS UK Ltd. (2015). (rep.). *Study to Model the Impact of Controlling Endemic Cattle Diseases and Conditions on National Cattle Productivity, Agricultural Performance and Greenhouse Gas Emissions.* Defra / Animal Health & Veterinary Laboratories Agency.
2. Almaraz, Maya; Houlton, Benjamin Z.; Clark, Michael; Holzer, Iris; Zhou, Yanqiu; Rasmussen, Laura; et al. (2023). Model-based scenarios for achieving net negative emissions in the food system. *PLOS Climate*. Collection. https://doi.org/10.1371/journal.pclm.0000181
3. Archer SC, Hudson CD, Green MJ (2015) Use of Stochastic Simulation to Evaluate the Reduction in Methane Emissions and Improvement in Reproductive Efficiency from Routine Hormonal Interventions in Dairy Herds. *PLoS ONE* 10(6): e0127846. https://doi.org/10.1371/journal.pone.0127846
4. Arndt, K. A., Campbell, E. E., Dorich, C. D., Grandy, A. S., Griffin, T. S., Ingraham, P., ... & Contosta, A. R. (2022). Initial soil conditions outweigh management in a cool-season dairy farm's carbon sequestration potential. *Science of the Total Environment*, 809, 152195.
5. Askew, K. (2022, July 8). *From date labels to packaging innovation and bioactive cultures: IFF discusses the complex topic of tackling food waste in dairy*. foodnavigator.com. https://www.foodnavigator.com/Article/2022/07/08/IFF-discusses-tackling-food-waste-in-dairy#
6. Buller, H., Blokhuis, H., Jensen, P., & Keeling, L. (2018). Towards farm animal welfare and sustainability. *Animals*, 8(6), 81.

References

7. Brown, D. R., & Brooke, C. (2023, August 13). *Climate-smart cattle: US research and development will improve animal productivity, address greenhouse gases, and hasten additional market solutions*. Federation of American Scientists. https://fas.org/publication/climate-smart-cattle/
8. Campbell, B. M., Thornton, P., Loboguerrero, A. M., Dinesh, D., & Nowak, A. (2023). *Transforming food systems under climate change through innovation.* Cambridge University Press.
9. CEIC Data. (2021). *Slovakia Agricultural Production: Livestock*. CEIC. https://www.ceicdata.com/en/slovakia/agricultural-production-livestock/
10. Climate and Clean Air Coalition. (2021). *Homepage: Global Methane Pledge*. Homepage | Global Methane Pledge. https://www.globalmethanepledge.org/
11. The Cool Farm Alliance. (2023). *Cool Farm Tool: An online greenhouse gas water and biodiversity calculator.* Cool Farm Tool. https://coolfarm.org/
12. Dairy Sustainability Framework. (2019). (rep.). *Dairy Sustainability Framework 2020-2025 Strategic Plan*. Retrieved September 20, 2023, from https://www.dairysustainabilityframework.org/wp-content/uploads/2022/06/DSF-Strategic-Plan-2020-2025.pdf.
13. DSF. (2023, May 11). *Dairy Sustainability Framework | Home*. Dairy Sustainability Framework. https://www.dairysustainabilityframework.org/
14. Costa Jr, C., Wollenberg, E., Benitez, M., Newman, R., Gardner, N., & Bellone, F. (2022). Roadmap for achieving net-zero emissions in global food systems by 2050. *Scientific reports*, 12(1), 15064.

References

15. Dallago GM, Wade KM, Cue RI, McClure JT, Lacroix R, Pellerin D, Vasseur E. Keeping Dairy Cows for Longer: A Critical Literature Review on Dairy Cow Longevity in High Milk-Producing Countries. *Animals* (Basel). 2021 Mar 13;11(3):808. doi: 10.3390/ani11030808. Erratum in: *Animals* (Basel). 2021 Oct 14;11(10): PMID: 33805738; PMCID: PMC7999272.
16. De Vries, A., & Marcondes, M. I. (2020). Overview of factors affecting productive lifespan of dairy cows. *Animal*, 14(S1), s155-s164.
17. Diavão, J., Silva, A. S., Sguizzato, A. L. L., Silva, C. S. D., Tomich, T. R., & Pereira, L. G. R. (2023). How does reproduction account for dairy farm sustainability?. *Animal Reproduction*, 20, e20230066.
18. dsm-firmenich. (2023, May 22). *Bel makes milk low-methane, working across its entire Slovakian dairy chain with partner dsm-firmenich.* @dsmFirmenich-corporate. https://www.dsm-firmenich.com/corporate/news/press-releases/2023/bel-is-rolling-out-bovaer-across-slovakian-dairy-chain.html
19. Erbach, G. (2021). *Climate action in Slovakia* (PE 698.767). European Parliamentary Research Service.
20. European Commission. (2020). *A farm to fork strategy for a fair, healthy and environmentally-friendly food system. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0381*
21. FAO. (2013). (rep.). *Food wastage footprint impacts on natural resources: Summary report.*
22. FAO. 2019. *Five practical actions towards low-carbon livestock*. Rome
23. FAO. (2023). *Dashboard | Global Livestock Environmental Assessment Model (GLEAM)* | Food and Agriculture Organization of the United Nations. https://www.fao.org/gleam/dashboard/en/

References

24. FAO and GDP. 2018. *Climate change and the global dairy cattle sector – The role of the dairy sector in a low-carbon future*. Rome. 36 pp. License: CC BY-NC-SA- 3.0 IGO
25. Farm Animal Welfare Committee. (2016). (rep.). *Sustainable agriculture and farm animal welfare*. Farm Animal Welfare Committee. Retrieved September 19, 2023, from http://www.gov.uk/government/collections/fawc-advice-to-government
26. Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A. & Tempio, G. 2013. *Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities*. Food and Agriculture Organization of the United Nations (FAO), Rome.
27. Hannah Ritchie (2019) - "Food production is responsible for one-quarter of the world's greenhouse gas emissions". Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/food-ghg-emissions' [Online Resource]
28. Hawkins, J., Yesuf, G., Zijlstra, M., Schoneveld, G. C., & Rufino, M. C. (2021). Feeding efficiency gains can increase the greenhouse gas mitigation potential of the Tanzanian dairy sector. *Scientific reports*, 11(1), 4190.
29. Holstein Association USA, Inc. (2023). *Holstein 101: A Beginner's Guide to Holstein Cattle*. Holstein 101. https://www.holsteinusa.com/holstein_breed/holstein101.html#:~:text=Holstein%20cows%20give%20more%20milk,gallons%2C%20of%20milk%20each%20lactation
30. Kebreab, E., Ahmadi, A., & Corner-Dolloff, C. (2019, November 25). *Ration Formulation Software Enhances Farmer Productivity, Decreases Emission Intensity and Trains Nutritionists in Vietnam*. Agrilinks. https://agrilinks.org/post/ration-formulation-software-enhances-farmer-productivity-decreases-emission-intensity-and

References

31. Khatri-Chhetri, A., Sapkota, T. B., Sander, B. O., Arango, J., Nelson, K. M., & Wilkes, A. (2021). Financing climate change mitigation in agriculture: assessment of investment cases. *Environmental Research Letters*, 16(12), 124044.

32. Knight, A. (2021, April 21). *How Heifer Prevents Zoonotic Diseases, Improves Animal Well-Being.* Heifer International. https://www.heifer.org/blog/how-heifer-prevents-zoonotic-diseases-improves-animal-well-being.html

33. Lazíková J, Lazíková Z, Takáč I, Rumanovská Ľ, Bandlerová A. Technical Efficiency in the Agricultural Business—The Case of Slovakia. *Sustainability*. 2019; 11(20):5589. https://doi.org/10.3390/su11205589

34. Ministry of Environment of the Slovak Republic. (2020). *Greener Slovakia—Strategy of the environmental policy of the Slovak Republic until 2030*. http://www.minzp.sk/iep/strategicke-materialy/envirostrategia-2030/

35. Muscat, A., de Olde, E.M., Ripoll-Bosch, R. *et al*. Principles, drivers and opportunities of a circular bioeconomy. *Nat Food* 2, 561–566 (2021). https://doi.org/10.1038/s43016-021-00340-7

36. National Milk Producers Federation. (2022, July 29). *Dairy Industry Sustainability Initiatives: NMPF Environmental Stewardship*. NMPF. https://www.nmpf.org/issues/sustainability/climate-policy/

37. Peterson CB and Mitloehner FM (2021) Sustainability of the Dairy Industry: Emissions and Mitigation Opportunities. *Front. Anim. Sci.* 2:760310. doi: 10.3389/fanim.2021.760310

38. Smith, J., & Tarawali, S. (2022, November 14). *ILRI's Jimmy Smith on bringing science-based nuance and clarity to today's polarized livestock debates*. ILRI | CGIAR. https://www.ilri.org/news/ilris-jimmy-smith-bringing-science-based-nuance-and-clarity-todays-polarized-livestock-debates

39. Tan, Zhibo. (2022). *Climate mitigation in Slovakia: targets, policies, and challenges.* International Monetary Fund.

References

40. Thorbecke, M., & Dettling, J. (2019). (rep.). *Carbon Footprint Evaluation of Regenerative Grazing at White Oak Pastures*. Quantis. Retrieved September 19, 2023, from https://blog.whiteoakpastures.com/hubfs/WOP-LCA-Quantis-2019.pdf.
41. U.S. Department of State & European Union. (2022, November 17). *Global Methane Pledge: From Moment to Momentum - United States Department of State*. U.S. Department of State. https://www.state.gov/global-methane-pledge-from-moment-to-momentum/
42. U.S. Environmental Protection Agency. (2022, December 15). Practices to Reduce Methane Emissions from Livestock Manure Management ... EPA.gov. https://www.epa.gov/agstar/practices-reduce-methane-emissions-livestock-manure-management
43. UC Davis. (n.d.). *Global Farm Animals Ration Programs (GlobalFARP)*. GEO Software - Global Engagement Office: Software Design, Development, Support and Distribution. https://geosoftware.faculty.ucdavis.edu/
44. United Nations Food and Agricultural Organization. (2023). *Livestock and enteric methane*. FAO. https://www.fao.org/in-action/enteric-methane/en/
45. USAID. (2022). *USAID climate strategy 2022-2030.* https://www.usaid.gov/sites/default/files/2022-11/USAID-Climate-Strategy-2022-2030.pdf
46. United States Department of Agriculture. (n.d.). *Partnerships for climate-smart commodities.* USDA. https://www.usda.gov/climate-solutions/climate-smart-commodities

References

47. USAID, RuMeth, & RTI International. (2022). (rep.). *METHANE REDUCTIONS AND DAIRY How can smallholder farmers increase production while reducing their methane footprint?* USAID. Retrieved September 19, 2023, from https://www.usaid.gov/sites/default/files/2023-03/Methane%20Reductions%20and%20Dairy%202%20pager.pdf.

48. USDairy.com. (August 2022). *U.S. Dairy Net Zero Initiative*.

49. von Soosten D, Meyer U, Flachowsky G, Dänicke S. Dairy Cow Health and Greenhouse Gas Emission Intensity. *Dairy*. 2020; 1(1):20-29. https://doi.org/10.3390/dairy1010003

50. van Zanten, H.H.E., Simon, W., van Selm, B. et al. Circularity in Europe strengthens the sustainability of the global food system. *Nat Food* 4, 320–330 (2023). https://doi.org/10.1038/s43016-023-00734-9

51. Wiesner, S., Duff, A. J., Desai, A. R., & Panke-Buisse, K. (2020). Increasing dairy sustainability with integrated crop–livestock farming. *Sustainability*, 12(3), 765.

52. World Bank Group. (2022, February 22). *Moving Towards Sustainability: The Livestock Sector and the World Bank.* World Bank. https://www.worldbank.org/en/topic/agriculture/brief/moving-towards-sustainability-the-livestock-sector-and-the-world-bank

53. Yost, C. (2022, December 13). *Have Your Cows Repaid their Debts?.* Penn State Extension. https://extension.psu.edu/have-your-cows-repaid-their-debts

54. Zahradnik, M. (2023). *Agricultural sector in Slovakia: Historical evolution, Current Status and Perspectives. National Agricultural and Food Centre, Research Institute for Animal Production Nitra.*