REDUCING ANIMAL AGRICULTURE EMISSIONS: THE VIABILITY OF A FARM TRANSITION CARBON OFFSET PROTOCOL

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SUMMARY

Animal agriculture is one of the leading sources of greenhouse gas emissions. Carbon offset markets allow entities to reduce their overall climate impact by financing projects that decrease emissions elsewhere. This Article analyzes the viability of an offset protocol that credits farms for transitioning from raising livestock to growing crops, based on the difference in emissions between these operations. It finds that a livestock-to-plants farm transition project can satisfy all of the criteria for offset protocols, and provides a preliminary methodology to calculate the emission reductions associated with a farm transition. Carbon offset registries, legislative bodies, and administrative agencies may implement these findings to help address the environmental and social harms associated with our current food system.

A recent Intergovernmental Panel on Climate Change (IPCC) report states that "aggressive policies" are essential for limiting the catastrophic harm to natural and human systems associated with global warming beyond 1.5 degrees Celsius (°C).[1] Animal agriculture is one of the leading sources of greenhouse gas (GHG), responsible for 14.5% of global emissions.[2] Further, the IPCC estimates that agricultural emissions will increase by 40% by 2050 without strong interventions.[3] Simply put, achieving the Paris Agreement's goals will be nearly impossible without ambitious policies that reform our food system.[4]

Despite the growing awareness of animal agriculture's climate impact,[5] climate policy and action have historically focused on electricity and fuel use.[6] California's cap-and-trade bill, arguably the most ambitious climate legislation in the nation, regulates energy emissions while exempting agriculture from its purview.[7] Similarly, the Green New Deal aims to address the issue of climate change by focusing on infrastructure and transportation measures, with soil health being the only substantive proposal in the agri-

1. Joeri Rogelj et al., *Mitigation Pathways Compatible With 1.5°C in the Context of Sustainable Development*, *in* Global Warming of 1.5°C 93, 149 (Valérie Masson-Delmotte et al. eds., IPCC 2018), https://www.ipcc.ch/site/assets/uploads/sites/2/2019/02/SR15_Chapter2_Low_Res.pdf.
2. IPCC, Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems (Priyadarshi R. Shukla et al. eds., 2019).
3. *Id.*
4. Walter Willett et al., *Food in the Anthropocene: The EAT-Lancet Commission on Healthy Diets From Sustainable Food Systems*, 393 Lancet 447 (2019).
5. *See, e.g.*, Henry Fountain, *Cutting Greenhouse Gases From Food Production Is Urgent, Scientists Say*, N.Y. Times (Nov. 5, 2020), https://www.nytimes.com/2020/11/05/climate/climate-change-food-production.html; Damian Carrington, *Avoiding Meat and Dairy Is "Single Biggest Way" to Reduce Your Impact on Earth*, Guardian (May 31, 2018), https://www.theguardian.com/environment/2018/may/31/avoiding-meat-and-dairy-is-single-biggest-way-to-reduce-your-impact-on-earth; Chris Mooney, *The Profound Planetary Consequences of Eating Less Meat*, Wash. Post (Mar. 21, 2016), https://www.washingtonpost.com/news/energy-environment/wp/2016/03/21/the-incredible-planetary-consequences-of-a-vegetarian-diet/.
6. *See, e.g.*, Energy Policy and Conservation Act of 1975, Pub. L. No. 94-163, §§321-339, 89 Stat. 871 (mandating vehicle fuel economy standards); Energy Policy Act of 2005, Pub. L. No. 109-58, §§1332-1337, 119 Stat. 594 (creating tax credit for energy-efficient appliances and construction of energy-efficient buildings); Energy Independence and Security Act of 2007, Pub. L. No. 110-140, §§102, 301-325, 121 Stat. 1492 (raising vehicle fuel efficiency standards and revising efficiency standards for home appliances and lighting); Energy Improvement and Extension Act of 2008, Pub. L. No. 110-343, §205, 122 Stat. 3765 (creating tax credit for plug-in electric vehicles).
7. California Air Resources Board, Unofficial Electronic Version of the Regulation for the California Cap on Greenhouse Gas Emissions and Market-Based Compliance Mechanisms (2019), https://ww2.arb.ca.gov/sites/default/files/2021-02/ct_reg_unofficial.pdf.

cultural sector.[8] More recently, however, bipartisan coalitions in the U.S. House of Representatives and U.S. Senate have sought to pass legislation that looks to rein in carbon emissions from certain aspects of agriculture by using voluntary carbon offset markets.[9]

There are many ways governments and corporations can reduce GHG emissions from animal agriculture. Beyond controversial carbon sequestration and biodigester programs, large investments in the research and development of plant-based and cultivated meats can spur innovations that increase the desirability of these substitutes by addressing their taste, price, and convenience—the traditional drivers of consumer food preferences.[10] Additionally, governments can require that agribusiness internalize the environmental, public health, and animal welfare costs of animal farms through regulations, mandates, or taxes.[11]

However, one food system policy idea has not received sufficient attention: the direct funding of farm transitions from concentrated animal feeding operations (CAFOs) to plant-based operations. Livestock-to-plants farm transitions follow the model of successful sustainable energy policy.[12] In the same way that governments help finance transitions from fossil fuels to renewable energy,[13] climate policies should consider funding transitions from CAFOs to plant-based farms.

In this Article, we present a market-based policy mechanism for mitigating GHG emissions from animal agriculture by harnessing carbon offset markets to finance the transition of livestock farms to plant-based production. Following a short background section, Part II assesses the performance and integrity of this mechanism by using industry-standard criteria for offset protocol certification. In particular, we address how to consider the additionality, permanence, realness, and leakage of emission reductions generated by livestock-to-plant-based farm transition. The Article and its online Appendices then move to outlining the equations and reputable emission factors that offset registries, administrative agencies, and legislative bodies can use to calculate the emission reductions associated with an individual farmer's transition from livestock to plants. Part III discusses the implications, and concludes.

In brief, offset credits for a livestock-to-plants farm transition would be measured as the difference in emissions between the livestock farm and the transitioned plant-based farm. After analyzing theoretical and empirical evidence, we estimate that a livestock-to-plants farm transition may merit offset credits equivalent to approximately three years of that livestock farm's emissions, after accounting for the leakage factor. As an example, the calculations in Appendix C demonstrate that transitioning a farm of 1,000 dairy cows results in emission reductions of 33,394 metric tons of carbon dioxide equivalent (CO_2e) over a 10-year crediting period.[14]

The main limiting factor for the length of time that a farm deserves emission reductions is the effect of "leakage," which, in this context, relates to the growth of nearby livestock farms that results from the market adjusting to the decreased herd size from the transitioned farm. Leakage is ultimately dependent on the ability and speed at which nearby farms are able to adjust their herd sizes, which is influenced by demand and supply elasticities for livestock products. Thus, there is also a large potential to receive carbon offset credits for additional years of emission reductions, as the demand elasticity of animal products increases through the improvement of plant-based alternatives, and as the supply rebound elasticity decreases as regulations are placed on industrial animal farming, such as a moratorium on the creation and expansion of CAFOs.

I. Background and Context

Animal agriculture produces significantly more GHGs than crop production for several reasons. First, farmed animals must consume crops to produce edible meat. Animals convert crop calories to meat calories at less than a one-to-one ratio, causing the vast majority of input calories to be wasted as feces, heat, or inedible body parts.[15] For example, a single kilogram (kg) of edible beef may require up to 25 kg of feed.[16] Animal agriculture increases the demand for feed production, which exacerbates environmental harms such as deforestation, land use changes, fertilizer use, processing, and transportation.[17]

Additionally, ruminant farmed animals produce tremendous amounts of methane through the digestive process known as enteric fermentation.[18] Methane is 84-86 times more powerful at trapping heat than CO_2 over a 20-year time frame and 28-34 times more powerful over a 100-year time frame.[19] Some farmed animals also produce significant amounts of methane and nitrous oxide from

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8. H.R.J. Res. 109, 116th Cong. (2019).
9. Growing Climate Solutions Act of 2021, S. 1251, 117th Cong. (2021), https://www.congress.gov/bill/117th-congress/senate-bill/1251; Growing Climate Solutions Act of 2021, H.R. 2820, 117th Cong. (2021), https://www.congress.gov/bill/117th-congress/house-bill/2820.
10. Deloitte, Capitalizing on the Shifting Consumer Food Value Equation (2016), https://www2.deloitte.com/content/dam/Deloitte/us/Documents/consumer-business/us-fmi-gma-report.pdf.
11. Pierre J. Gerber et al., Food and Agriculture Organization of the United Nations, Tackling Climate Change Through Livestock: A Global Assessment of Emissions and Mitigation Opportunities (2013).
12. Jonathan Lovvorn, *Clean Food: The Next Clean Energy Revolution*, 36 Yale L. & Pol'y Rev. 283 (2018).
13. Congressional Research Service, R44852, The Value of Energy Tax Incentives for Different Types of Energy Resources (2019).
14. Appendix C is available at https://www.eli.org/sites/default/files/files-pdf/Rutinel-Quaade-Appendices.pdf.
15. LibreTexts Biology, *Transfer of Energy Between Trophic Levels*, https://bio.libretexts.org/@go/page/14227 (last updated June 8, 2022).
16. *Facts and Figures*, *in* Poultry Production Manual 2.1, 2.2 (University of Kentucky, College of Agriculture & Kentucky Poultry Federation), https://afs.ca.uky.edu/files/chapter2.pdf.
17. Henning Steinfeld et al., Food and Agriculture Organization of the United Nations, Livestock's Long Shadow: Environmental Issues and Options (2006).
18. *Id.*
19. Gunnar Myhre et al., *Anthropogenic and Natural Radiative Forcing*, *in* Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change 659, 714 tbl.8.7 (T.F. Stocker et al. eds., Cambridge Univ. Press 2013).

their excrement, particularly as it is handled on CAFOs.[20] Nitrous oxide is a GHG that is 265-298 times more powerful at trapping heat than CO_2 on a 100-year time frame.[21]

Although not explicitly a climate policy, Sen. Cory Booker (D-N.J.)'s proposed Farm System Reform Act includes a debt forgiveness and transition assistance program for farmers wanting to transition from a CAFO to a plant-based operation.[22] More in line with a vision of a farm transition climate policy, California Assemblymember Ash Kalra recently introduced the Smart Climate Agriculture Program, which would provide grants to animal farms wanting to transition to plant-based agriculture.[23] The United States can also look abroad for inspiration for such policies, with Denmark recently passing an agricultural bill pledging more than $90 million in bonuses for farmers who grow plant-based crops for human consumption.[24]

In addition to legislative proposals offering grants for farm transitions, carbon offset markets are a still-unexplored strategy to mitigate GHG emissions through farm transitions. Offset credit programs allow entities within both voluntary and mandatory carbon markets to decrease their emissions by funding a project that reduces emissions in another sector of the economy.[25] Offset programs function through the establishment of offset protocols, which are the accounting rules and program requirements for monitoring, reporting, verification, and certification.[26] In addition to their usefulness in the creation of an offset protocol, these criteria are an important starting point for legislative proposals with a similar structure and motive.

II. Carbon Offset Criteria

A. *Offset Credit Overview*

An offset credit is granted to its purchaser by a government agency or independent certifier as a representation of an emission reduction equivalent to one metric ton of CO_2.[27] They allow individuals and businesses to diminish their emissions by funding a project that reduces emissions in another sector of the economy. For example, a manufacturing facility in California can decrease its net emissions by purchasing offset credits that finance a reforestation project in Brazil.

Offset credits can be purchased voluntarily or to exceed emission allowances within a compliance market. Compliance offset markets exist within carbon reduction regimes (e.g., cap and trade) in nations, regions, and states worldwide.[28] Because offset credits within compliance markets often require higher standards and because regulatory obligations drive their demand, compliance offset credit prices tend to be higher than the offset credits in the voluntary market.[29] Further, voluntary carbon offsets vary widely in price based on project type, location, and verification body.[30]

Certain carbon offset projects contribute to other environmental benefits beyond GHG reduction that can be exchanged for additional credits. The act of collecting multiple types of credits for a single project is known as credit stacking.[31] Because transitioning a CAFO includes numerous environmental co-benefits, it has a tremendous potential to benefit from credit stacking in the domains of water, land, biodiversity, and air. Additionally, with the rising importance of the United Nations Sustainable Development Goals (SDGs) and the emergence of entities aiming to certify and finance beneficial SDG practices, farm transitions can further benefit from their non-climate co-benefits.[32]

Many types of projects can qualify for offset credits. However, a project's qualification depends on the specific standards of the government agency within a compliance market or the offset program within a voluntary market. For instance, the California Air Resources Board (CARB) accepts projects for forests, mine methane capture, ozone-depleting substances, rice cultivation, and livestock biogas.[33] Other voluntary offset programs finance projects relating to renewable energy sources, fuel-efficient cooking and water filtration systems in developing nations, waste management, and many more.[34]

In general, an offset project is legitimate if it meets the following criteria: additional, conservative, permanent, verifiable, and avoids social and environmental harms.[35]

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20. Steinfeld et al., *supra* note 17.
21. Myhre et al., *supra* note 19, tbl.8.7.
22. Farm System Reform Act of 2019, S. 3221, 116th Cong. (2019), https://www.congress.gov/bill/116th-congress/senate-bill/3221/text.
23. Smart Climate Agriculture Program: Plant-Based Agriculture, A.B. 1289, 2021-2022 Leg., Reg. Sess. (Cal. 2021), https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220AB1289.
24. *Regeringen Indgår Bred Aftale Om Grøn Omstilling Af Dansk Landbrug*, Finansministeriet (Oct. 4, 2021) (Den.), https://fm.dk/nyheder/nyhedsarkiv/2021/oktober/regeringen-indgaar-bred-aftale-om-groen-omstilling-af-dansk-landbrug/.
25. Carbon Offset Guide, *Mandatory & Voluntary Offset Markets*, https://www.offsetguide.org/understanding-carbon-offsets/carbon-offset-programs/mandatory-voluntary-offset-markets/ (last visited Sept. 27, 2022).
26. Carbon Offset Guide, *Protocols & Standards*, https://www.offsetguide.org/understanding-carbon-offsets/carbon-offset-programs/protocols-standards/ (last visited Sept. 27, 2022).
27. Carbon Offset Guide, *What Is a Carbon Offset?*, http://www.offsetguide.org/understanding-carbon-offsets/what-is-a-carbon-offset/ (last visited Sept. 27, 2022).
28. *See*, *e.g.*, California Air Resources Board, *Compliance Offset Program*, https://ww2.arb.ca.gov/our-work/programs/compliance-offset-program (last visited Sept. 27, 2022).
29. Carbon Offset Guide, *supra* note 25.
30. Stephen Donofrio et al., Ecosystem Marketplace, Voluntary Carbon and the Post-Pandemic Recovery: A Special Climate Week NYC 2020 Installment of Ecosystem Marketplace's *State of Voluntary Carbon Markets 2020* Report (2020), https://wecprotects.org/wp-content/uploads/2020/11/EM-Voluntary-Carbon-and-Post-Pandemic-Recovery-2020.pdf.
31. Royal C. Gardner & Jessica Fox, *The Legal Status of Environmental Credit Stacking*, 40 Ecology L.Q. 713 (2013), *available at* http://www.jstor.org/stable/24113683.
32. Adva Saldinger, *A Deepening Relationship Between Impact Investing and the SDGs*, Devex (Nov. 21, 2019), https://www.devex.com/news/a-deepening-relationship-between-impact-investing-and-the-sdgs-96075.
33. California Air Resources Board, *supra* note 28.
34. Gold Standard Marketplace, *Offset Your Emissions*, https://marketplace.goldstandard.org/collections/projects (last visited Sept. 27, 2022).
35. Carbon Offset Guide, *What Makes a High-Quality Carbon Offset?*, https://www.offsetguide.org/high-quality-offsets/ (last visited Sept. 27, 2022).

The following sections define each of these criteria and analyze how they each relate to farm transition projects.

B. Additional

GHG reductions are said to be additional if they would not have occurred in the absence of a carbon offset credit.[36] If the GHG reductions occur because of mandatory regulations or if the change would have occurred in the business-as-usual scenario, then the offset project is not additional.

In line with other livestock protocols, the lack of laws mandating farm transitions or lower GHG emissions from livestock production makes farm transitions entirely additional concerning regulatory compliance.[37] Further, the farming practices that livestock farmers use are what they believe to be the most profitable given the debt and capital they hold, and there are no technologies available that would induce GHG reductions without an offset credit intervention.[38] As such, an offset credit program that finances farm transitions from animals to plants satisfies the additionality criteria of regulatory surplus.[39]

In some protocols, additionality is identified according to a "barrier analysis," in which a project is deemed additional in the presence of financial, technological, institutional, or regulatory barriers to uptake of the offset activity.[40] Farm transitions are primarily affected by financial barriers. If a review of a farmer's financial position demonstrates that they do not have the means to conduct a farm transition, or that a farm transition would not yield higher profits than their baseline activity without including offset credits, then the farm transition can be said to be additional.

Additionality can also be identified by the uptake of the activity that is reducing GHG emissions, a procedure known as "performance benchmarking."[41] This approach sets a threshold penetration rate for the adoption of the offset activity within a geographic region, below which the adoption of the offset activity can be said to be additional. Farm transitions can be seen as a new activity or practice. As such, a conservation easement that mandates the retirement of livestock-specific infrastructure, and prohibits livestock and feed production while allowing grasslands, forests, or human-edible crops, is a new practice that should be considered additional until it covers some proportion of active livestock operations within a region that is defined in the protocol.

C. Conservative and Real

A conservative methodology for an offset protocol is important to ensure an appropriate number of offset credits are issued. Granting more offset credits than appropriate may lead to worse climate outcomes if the business purchasing the offset credit did so in place of reducing their own emissions. Overestimation of GHG reductions occurs in the following ways: overestimating baseline emissions, underestimating project emissions, and neglecting indirect effects (e.g., leakage).[42]

Baseline emissions are the emissions that would have occurred in the absence of an offset credit program. In a livestock operation, baseline emission sources may include manure management, enteric fermentation, feed production, land use change, and the use of equipment, facilities, and transportation. Creating appropriate baseline emissions requires a comprehensive understanding of each of these emission sources. Fortunately, many independent scientists and institutions, such as the IPCC, have researched most of these emission sources extensively in the context of livestock operations, enabling an accurate and conservative emissions accounting.[43]

Project emissions relate to emission quantities that a project would emit if the offset project is implemented. These must be calculated appropriately since offset credits are issued by subtracting project emissions from baseline emissions. In the case of a cropland operation, project emissions would result from fertilizer use, cropland management practices, land use change, equipment, facilities, and transportation.[44]

Given a livestock operation's extensive need for heating, lighting, ventilation, milking equipment, feed, feeding equipment, and manure management systems, a livestock operation will likely produce much greater emissions than a cropland operation for every category of cropland emission. Thus, this project proposal can use an overly conservative approach to its methodology by not considering the emission sources that the baseline and project have in common. Alternatively, the offset protocol can use some of the well-researched estimates outlined in scientific journals and other protocols to calculate emissions from each of these sources.[45]

D. Indirect Effects and Leakage

Projects will often have intended and unintended effects outside of the narrow conception of the project boundary. Unintended increases in GHG emissions caused by a proj-

36. Verra, Verified Carbon Standard: Methodology Requirements v4.1 (2022), https://verra.org/wp-content/uploads/2022/01/VCS-Methodology-Requirements_v4.1.pdf.
37. Climate Action Reserve, *U.S. Livestock Protocol*, https://www.climateactionreserve.org/how/protocols/us-livestock/ (last visited Sept. 27, 2022).
38. *Id*.
39. Verra, *supra* note 36.
40. Pedro Martins Barata, *Carbon Credits and Additionality: Past, Present, and Future* (World Bank, PMR Technical Note No. 13, 2016).
41. *Id*.
42. Carbon Offset Guide, *Avoiding Overestimation*, https://www.offsetguide.org/high-quality-offsets/avoiding-overestimation/ (last visited Sept. 27, 2022).
43. U.S. Environmental Protection Agency, Annexes to the Inventory of U.S. GHG Emissions and Sinks (2021), https://www.epa.gov/sites/production/files/2021-04/documents/us-ghg-inventory-2021-annexes.pdf.
44. Climate Action Reserve, *Grassland Protocol*, https://www.climateactionreserve.org/how/protocols/grassland/ (last visited Sept. 27, 2022).
45. U.S. Environmental Protection Agency, *supra* note 43.

ect are known as "leakage." To avoid overestimating the net emissions reduced by the project, methodologies must adequately quantify these possible leakage effects when they are expected to be significant. One prominent example of leakage is a forest preservation project that prevents one parcel of land from deforestation, but ultimately shifts the deforestation to another parcel of land.[46] It is likely that farm transitions will induce considerable leakage as supply rebounds through the expansion and creation of other farms in the aftermath of an exogenous reduction.

Leakage for this protocol can result from two different channels: (1) the displacement of farmed animals onto other farms, and (2) the expansion or entry of farms in response to the price increases caused by the fall in supply of the animal product.

Regarding the direct displacement of the animals on the farm, this Article recommends including a project requirement that farmers are not allowed to sell their livestock to active farmers in the offset protocol. With this requirement, we anticipate that, in nearly all instances, farmers will sell their animals to a slaughterhouse when transitioning their farm, as it is in their economic interest to do so. In those instances, the Verified Carbon Standard (VCS) module related to "Leakage From Displacement of Grazing Activities" denotes that the leakage effect associated with the direct displacement of those animals is zero.[47] In instances in which the farmer gives the livestock to another farmer or sanctuary, the aforementioned module includes the relevant formulas for any leakage effects associated with the livestock's direct displacement.

With regard to new or existing farmers making up for reduced supply, the VCS "Estimation of Emissions From Market Leakage" (EEML) suggests that leakage effects are presumably negligible if the transitioned farm constitutes a small proportion of the production within its respective market.[48] This module first asks the project developer to identify whether the farmer is providing more or less than 3% of the supply of a given product to either their local, regional, national, or international markets. If the farmer provides less than 3% of the supply at a given market, price changes caused by the project are assumed to be indistinguishable from normal market "noise." As a result, any possible pricing change would not incentivize a change in the behavior of suppliers elsewhere and no leakage occurs.

Given that each type of livestock commodity is highly concentrated in regional clusters,[49] a small number of slaughterhouses manage the vast majority of animals for the nation,[50] and even the international market has relatively low trade barriers for livestock commodities,[51] it is unlikely that livestock farmers provide more than 3% of the supply of a given product in the vast majority of anticipated farm transitions. As such, according to this VCS module, market leakage would not apply for most implementations of this protocol proposal.

Of course, some livestock farmers may be large enough to claim a market share greater than 3% for a region, and numerous livestock farmers serving the same markets may together make up market shares greater than 3%. In instances where livestock farmers provide more than 3% of any geographic market's supply, the EEML module outlines the calculations necessary to determine the extent of the leakage effects.[52]

When high-quality evidence for estimating leakage effects using the EEML module is not available, other protocols account for leakage by making more conservative estimates. For instance, Climate Action Reserve's (CAR's) Grassland Protocol has leakage effects analogous to our proposed farm transition leakage protocol.[53] In the Grassland Protocol, a conservation easement applied to a grassland area is expected to prevent emissions associated with its conversion to cropland. The protocol estimates the avoided cropland emissions based on the expected tillage practices, cropping sequence, fertilizer and nutrient application, irrigation practices, and fuel consumption of the expected crop system on each strata of land.[54]

In other words, the Grassland Protocol assumes that the baseline level of emissions for the project area would be the emissions of a cropland operation, and preventing those practices grants the grassland operator offset credits based on this baseline. Similarly, our proposed livestock farm transition protocol assumes that baseline emissions for a livestock operation will continue and that transitioning to a crop operation would produce significantly lower emissions. CAR manages the leakage effect by taking the conservative approach of assuming a 20% leakage effect.[55] Using this value is conservative because CAR cites several studies that indicate leakage effects at much lower

46. Brian C. Murray et al., *Estimating Leakage From Forest Carbon Sequestration Programs*, 80 Land Econ. 109 (2004).
47. See "Grazing Displacement" definition on page 6 and Figure 1 on page 7 of Approved VCS Methodology Module VMD0040: Leakage From Displacement of Grazing Activities v1.0 (2014), https://verra.org/wp-content/uploads/2018/03/VMD0040-Leakage-from-Displacement-of-Grazing-Activities-v1.0.pdf.
48. VCS Module VMD0033: Estimation of Emissions From Market Leakage v1.0 (2012), https://verra.org/wp-content/uploads/2018/03/VMD0033-Estimation-of-Emission-from-Market-Leakage-v1.0.pdf.
49. William D. McBride, *Measuring Size in Livestock Production*, *in* Change in U.S. Livestock Production, 1969-92, at 4 (U.S. Department of Agriculture 1997), https://www.ers.usda.gov/webdocs/publications/40794/32769_aer754b1.pdf?v=41401.
50. James M. MacDonald et al., U.S. Department of Agriculture, Consolidation in U.S. Meatpacking (2000), https://www.ers.usda.gov/webdocs/publications/41108/18011_aer785_1_.pdf?v=8725.9.
51. As evidenced by the magnitude of imports and exports occurring for each livestock commodity: U.S. Department of Agriculture (USDA) Economic Research Service (ERS), *Livestock and Meat International Trade Data*, https://www.ers.usda.gov/data-products/livestock-and-meat-international-trade-data/ (last updated Sept. 8, 2022).
52. VCS Module VMD0033: Estimation of Emissions From Market Leakage v1.0, *supra* note 48.
53. Climate Action Reserve, *supra* note 44.
54. CAR, Grassland Project Protocol v2.1 §B.3 (2020), https://www.climateactionreserve.org/wp-content/uploads/2020/02/Grassland_Protocol_V2.1.pdf.
55. *Id*. §5.3.5.

levels.[56] CAR's Forest Protocol uses analogous reasoning and estimates.[57]

Finally, as noted in the EEML module, market rigidities may result in the market surplus of a product such that the exit of a supplier does not influence the incentives of others to enter the market or expand supply. As we outline in the following section, there are a number of conditions in animal product markets that generate market rigidities that may limit the extent of leakage. Such rigidities can be further strengthened by the inclusion of offset protocol project requirements that prevent the sale of livestock-specific equipment to other livestock farmers and prohibit transitioned farmers from working on other livestock operations.

Unlike many of the projects in CAR's Grassland and Forest Protocols, the livestock transition protocol allows for the continuation of strong commodity production on the transitioned farm, enabling farmers to feed the public in ways that displace the public's current consumption of animal products. In fact, VCS Methodology Requirements for Agriculture, Forestry, and Other Land Use (AFOLU) protocols generally assume that maintaining land for commodity production would make market leakage effects likely negligible.[58]

Additionally, unlike forest and grassland protocols, which credit projects for the sequestration of carbon and are reversible both within their own territory and if the process is displaced elsewhere, livestock transitions are nonreversible since they are simply reducing emissions relative to an assumed baseline. Thus, if deforestation or grassland conversion occurs elsewhere due to direct displacement or market leakage, whether it be instantly or in the future, the gains associated with the project will be sacrificed. However, livestock transition projects would be successful for as long as it takes the market to readjust back to its initial baseline.

1. Depressed Livestock Commodity Prices

With ever-growing health, environmental, and ethical concerns surrounding animal agriculture, the consumption of animal products is in some cases stagnating and decreasing. For instance, the U.S. Department of Agriculture (USDA) found that declining consumption has resulted in dairy availability per person in the United States falling from 339.2 pounds in 1970 to 275.9 pounds in 2012.[59] Similar trends exist for beef and pork.[60]

The question then becomes why these farmers would need help transitioning away from declining industries, rather than allowing market forces to independently phase out excess supply. There are two main market rigidities that prevent farm transitions from occurring on their own: government subsidies and the sunk cost of capital expenditures. Each of these effects are relevant to the assessment of additionality and leakage in farm transitions.

2. Government Subsidies

Government subsidies for livestock production come in many different magnitudes and types. The bulk of agricultural subsidies for American farmers are appropriated under the farm bill.[61] Historically, government subsidies have taken on many forms, including price floors,[62] government purchases of excess supply,[63] grants for exporting,[64] low-interest loans,[65] low-cost feed,[66] and the subsidization of insurance premiums.[67] Ultimately, by making production more profitable than the baseline market level, government subsidies incentivize farmers to increase production, particularly on environmentally sensitive and low-productivity lands.[68]

Figure 1 (next page) uses standard economic theory to demonstrate the role that subsidies play in shifting the supply curves of agricultural commodities. S1 represents a market in which the supply curve is subject only to the financial benefits and costs of the commodity in question absent any government subsidy. In S1, the suppliers are also obligated to internalize the costs of any externalities associated with production, such as the GHG emissions they

56. JuneJie Wu, *Slippage Effects of the Conservation Reserve Program*, 82 Am. J. Agric. Econ. 979 (2000); Michael J. Roberts & Shawn Bucholtz, *Slippage in the Conservation Reserve Program or Spurious Correlation? A Comment*, 87 Am. J. Agric. Econ. 244 (2005); Farzad Taheripour, Economic Impacts of the Conservation Reserve Program: A General Equilibrium Framework, Presentation at American Agricultural Economics Association Annual Meeting (July 23-26, 2006); David A. Fleming, Slippage Effects of the Conservation Reserve Program: New Evidence From Satellite Imagery, Presentation at Joint Annual Meeting of the Agricultural and Applied Economics Association & Western Agricultural Economics Association (July 25-27, 2010).
57. CAR, *Forest Protocol*, https://www.climateactionreserve.org/how/protocols/forest/ (last visited Sept. 27, 2022).
58. VCS Agriculture, Forestry, and Other Land Use (AFOLU) Requirements v3.6 §4.6.11 (2017), https://verra.org/wp-content/uploads/2020/11/PREVIOUS-VERSION-AFOLU-Requirements-v3.6.pdf.
59. Jeanine Bentley, *Trends in U.S. Per Capita Consumption of Dairy Products, 1970-2012*, USDA Amber Waves (June 2, 2014), https://www.ers.usda.gov/amber-waves/2014/june/trends-in-us-per-capita-consumption-of-dairy-products-1970-2012/.
60. USDA ERS, *Per Capita Availability of Chicken Higher Than That of Beef*, https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=58312 (last updated Jan. 14, 2021).
61. Agriculture Improvement Act of 2018, Pub. L. No. 115-334, 132 Stat. 4490.
62. Farm Service Agency, USDA, Fact Sheet: Milk Income Loss Contract Program (2006), https://www.fsa.usda.gov/Internet/FSA_File/milc06.pdf.
63. Farm Service Agency, USDA, Fact Sheet: Dairy Product Price Support Program (DPPSP), Formerly the Milk Price Support Program (MPSP) (2011), https://www.fsa.usda.gov/Internet/FSA_File/dppsp_en_fact_sheet.pdf; USDA Agricultural Marketing Service, *Food Purchase and Distribution Program*, https://www.ams.usda.gov/selling-food-to-usda/trade-mitigation-programs (last visited Sept. 27, 2022).
64. USDA Foreign Agricultural Service, *MAP Funding Allocations—FY 2021*, https://www.fas.usda.gov/programs/market-access-program-map/map-funding-allocations-fy-2021 (last visited Sept. 27, 2022).
65. USDA Farm Service Agency, *Farm Loan Programs*, https://www.fsa.usda.gov/programs-and-services/farm-loan-programs/ (last visited Sept. 27, 2022).
66. Timothy A. Wise, *Identifying the Real Winners From U.S. Agricultural Policies* (Tufts University Global Development and Environment Institute, Working Paper No. 05-07, 2005).
67. Risk Management Agency, USDA, Livestock Risk Protection Fed Cattle (2022), https://www.rma.usda.gov/-/media/RMA/Fact-Sheets/National-Fact-Sheets/LRP-Fed-Cattle.ashx?la=en.
68. Ruben N. Lubowski et al., USDA, Environmental Effects of Agricultural Land-Use Change: The Role of Economics and Policy (2006).

emit. S2 represents a market in which the suppliers are not required to internalize these externalities, and are therefore not subject to the entire costs of production. S3 represents the supply curve for a commodity that is both not subject to the internalization of its externalized costs, and is also the beneficiary of government subsidies that decrease the costs of production.

D1 represents the demand curve for the commodity in question, demonstrating the quantity demanded by consumers at any given price. P3 and Q3 are the price and quantity that result when the government gives suppliers a subsidy that decreases the costs of production. Alternatively, when the government sets a price floor of P4, suppliers produce quantity Q4 even though consumers only demand the lower quantity of Q5, creating a large glut of production.

Figure 1. Socially Optimal Supply, Supply With Externalities, Supply With Externalities and Subsidies, and Supply With a Price Floor

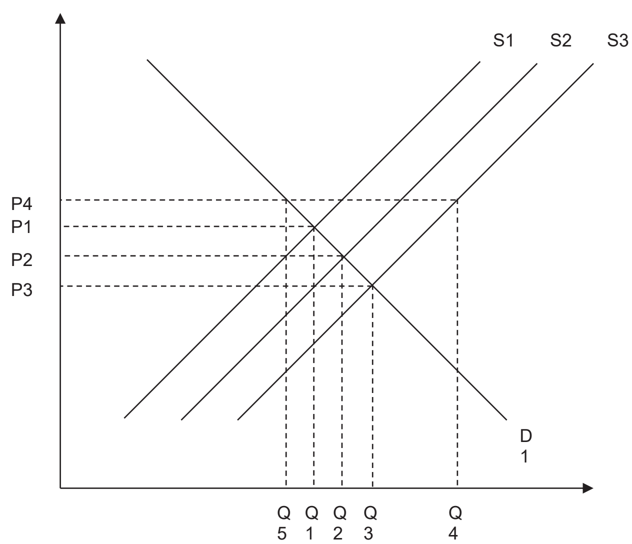
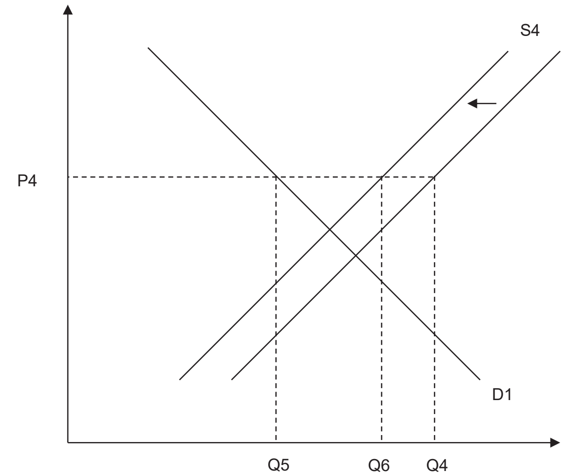


Figure 2 below demonstrates the effects of farm transitions in the context of an explicit price floor or the creation of a price floor through price-loss insurance subsidies. D1 again represents the demand curve for the commodity in question, demonstrating the quantity demanded by consumers at any given price. Because a farm transition eliminates capacity for production at any given price, this shifts the supply curve to the left from S3 to S4. This leftward shift in supply decreases the quantity supplied from Q4 to Q6 while the quantity demanded remains at Q5. Thus, in the context of price floors, a farm transition reduces overall capacity and quantity while not inducing any market signals in the form of increased price.

Because livestock production does not have to internalize the full costs of production, and because livestock producers receive subsidies from federal and state governments, their supply curve is artificially maintained at a rightward point from the socially optimal market baseline. As such,

Figure 2. Price Floor Subsidy



in the context of a price floor, the elimination of production capacity will not lead to price signals nor increased capacity from large livestock producers. An example of this exact phenomenon is the USDA Dairy Termination Program (DTP), which was created in the 1980s to decrease the glut of dairy production that the government incentivized through its price floor system, which also purchased excess supply to store in large warehouses.[69]

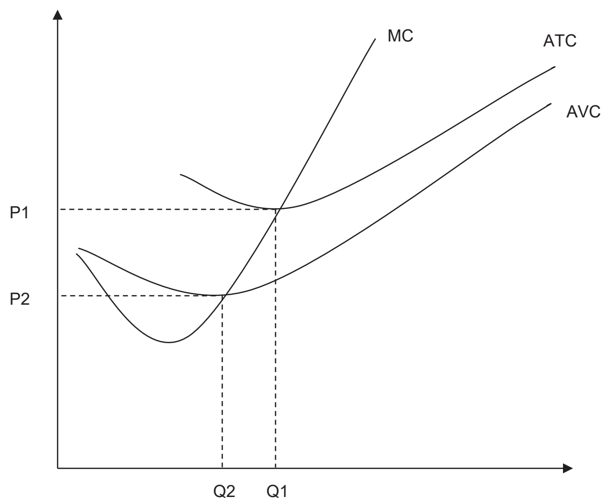
3. Sunk Cost of Capital Expenditures

Livestock farmers have fixed and variable costs. Fixed costs are costs that must be paid regardless of whether anything is produced. They include land, tractors, trucks, housing facilities, milking parlors, water infrastructure, and often the animals themselves.[70] Variable costs are directly linked to the level of output produced, and may include feed, fertilizer, electricity, labor, and veterinary fees. Figure 3 (next page) demonstrates the relationship between marginal cost (MC), average variable cost (AVC), average total cost (ATC), market price (P), and the amount the firm ultimately chooses to supply (Q).

For any given market price, farmers maximize their profits by producing along the MC curve at any point above the AVC curve. Any point along the MC curve above the ATC curve represents economic profits. Deficits result from production along the MC curve below the ATC curve, which includes the farmer's opportunity costs. However, because of the fixed costs already paid upfront, in the short run, farmers are incentivized to continue production at any market price above AVCs along the MC curve. Farmers in a competitive market will exit the industry in the long run

69. Bruce L. Dixon et al., *Supply Impact of the Milk Diversion and Dairy Termination Programs*, 73 Am. J. Agric. Econ. 633 (1991).
70. *See, e.g.*, John Moran, Business Management for Tropical Dairy Farmers (2009); Jeremy D. Foltz, *Entry, Exit, and Farm Size: Assessing an Experiment in Dairy Price Policy*, 86 Am. J. Agric. Econ. 594 (2004).

Figure 3. Firm Production Function



if price remains below ATCs. However, the long run represents a time at which farmers can either recover their fixed costs or their capital is no longer in its useful life, which may be after many years.[71]

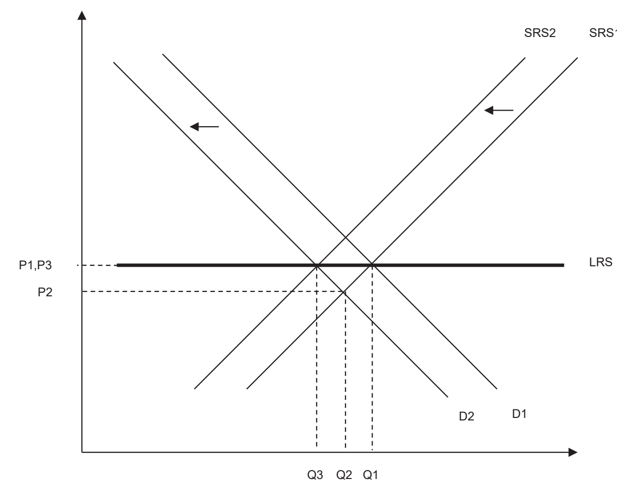
To demonstrate the role that sunk fixed costs play in both additionality and the leakage effects, we will briefly examine the dairy industry. An economic model analysis of large New York dairy farmers in 2006 found that the gap between the profitable price to enter the industry and the price to exit is very large, meaning that there is a large range in price within which farmers are unlikely to exit and also at which increases in price do not affect industry entrance.[72] An analysis of dairy farms during 2005 indicates that 29% of dairies with herd sizes over 1,000 did not earn gross returns above total costs and 12% did not even earn gross returns above variable costs, with smaller herd sizes increasingly less likely to be profitable.[73]

Given that recent milk prices have fluctuated around a similar price as those in 2005, it seems likely that there are still similarly significant numbers of dairy farmers operating below ATCs. With fluid cow milk consumption dropping precipitously,[74] future cow milk demand appears grim. Nevertheless, as is clear from Figure 3, dairy farmers may not readily exit the industry because they may be functioning above AVCs despite not making a profit. As a result, the short-run supply curve is to the right of the economically optimal long-run supply point. Further, the high levels of sunk costs in dairy production may lead to prolonged periods of economic losses and environmental pollution before the short-run supply curve eventually shifts to the left to reach its long-run point.

Figure 4 demonstrates the effects of the trend referenced above. It is possible that a growing awareness of the issues surrounding industrial animal agriculture alongside the growing availability of plant-based alternatives will shift demand for livestock commodities from D1 to D2. This leads prices to fall from P1 to P2 and quantities to fall from Q1 to Q2, resulting in decreased profits for the commodity producers. Because of the effects of sunk costs, as described above, farmers may only decide to downsize or exit the industry after a substantial amount of time.

This downsizing or exit would lead to a leftward shift in the supply curve from SRS1 to SRS2, which would bring supply to its long-run levels by raising prices from P2 to P3 while decreasing quantities from Q2 to Q3. LRS represents the long-run equilibrium points at which producers receive sufficient profits to continue operation. Thus, farm transitions may help enable markets to more efficiently reach their long-run equilibrium points while decreasing harmful, inefficient emission sources.

Figure 4. Short-Run Supply Shift in Response to Demand Shift



E. *Analytical Leakage Results*

Beyond the analogous carbon offset protocols examined above, there are two large-scale historical analogues to livestock-to-plants farm transitions within the United States. The first program is DTP, which was conducted by USDA from 1986 to 1987.[75] The second program was a dairy cooperative-led initiative known as the Herd Retirement Program (HRP), conducted by Cooperatives Working Together (CWT) from 2003 to 2010.[76]

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71. Nicole Heslip, *When Is It Time to Sell?*, Farm Progress (Mar. 15, 2018), https://www.farmprogress.com/dairy/when-it-time-sell.
72. Loren W. Tauer, When to Get In and Out of Dairy Farming: A Real Option Analysis, Presentation at the American Agricultural Economics Association Annual Meeting (July 24-26, 2006).
73. James M. MacDonald et al., USDA, Profits, Costs, and the Changing Structure of Dairy Farming (2007).
74. Hayden Stewart et al., *Are Plant-Based Analogues Replacing Cow's Milk in the American Diet?*, 52 J. Agric. & Applied Econ. 562 (2020).
75. Dixon et al., *supra* note 69.
76. Carissa J. McCay, Effect of Cooperatives Working Together Herd Retirements on the U.S. Dairy Herd Size (2011) (Departmental Honors

Both programs solicited farmers to submit bids for which they would be willing to export or slaughter their herds. DTP further prevented approved farmers from using their farms for the purposes of dairy production for five years. The main objective of DTP was to decrease the glut of dairy production that the government created through its price support system and that it ultimately purchased to merely store in large warehouses.[77] The main objective of CWT's program was to increase dairy prices by restricting its production, an objective for which they ultimately paid a $220 million settlement to lawsuits brought on antitrust grounds.[78]

The evidence from these studies suggests that significant leakage did eventually occur. Bruce Dixon et al. plot the percentage reduction in milk supply in the years after the implementation of DTP, finding that milk supply had rebounded by approximately 25% of the initial supply reduction after two years.[79] Similarly, Carissa McCay uses an econometric model of the U.S. dairy herd to estimate leakage from CWT's program.[80] McCay finds that, while the total market's dairy herd recovered by 50% of the initial supply loss within the same quarter, in the long term, the number of dairy cows is permanently reduced by 47% of the CWT dairy herd reduction.

Analyzing these programs and other studies pertaining to herd dynamics is important to determine the leakage effects associated with an exogenous reduction in herd sizes. However, it is important to also mention key distinctions between these former programs and a contemporary implementation of a farm transition protocol meant to reduce emissions, as many of the former programs may have had flexibilities or contexts that induced greater leakage.

For instance, it seems likely that the contemporary, ubiquitous availability of plant-based alternatives to dairy may decrease the inelastic nature of dairy products, though the research on this is inconclusive.[81] This claim requires further investigation, but its validity would make leakage a weaker concern today than in the past. Additionally, farmers participating in DTP and HRP were still able to grow feed crops, potentially creating price reductions for the inputs to dairy production. Also, farmers participating in a carbon offset protocol may be required to produce inputs that directly compete with dairy products, alleviating some of the potential demand gap for dairy products.

Rigorously estimating the extent of leakage requires understanding how prices change in the face of a supply reduction, and how consumers and other suppliers respond to these price movements. We can model these dynamics using price elasticities of supply and demand. Price elasticities of supply and demand describe the degree to which the supply of or demand for a product changes in response to a given change in the price within a given time period. In particular, products with a high elasticity of demand will see a large decrease in quantity demanded as its price increases, while products with a high elasticity of supply will see a large increase in supply when prices increase. By estimating the expected price change from a farm transition and then estimating how quickly other farmers increase their supply in response to that price signal, we can rigorously account for leakage using these concepts.

Figure 5 (next page) illustrates how markets will respond to a farm transition. In the first panel, the supply curve shifts leftward as a livestock farmer transitions to producing crops, causing a price increase from P1 to P2. The size of this price increase depends on (1) how far the supply curve shifts (how much supply is reduced) and (2) the elasticity of demand (i.e., the slope of the demand curve). The size of the price increase is important for understanding leakage, as small price increases are unlikely to be differentiated from standard market "noise," and larger price increases are going to encourage more aggressive increases in supply. For this reason, leakage is generally minimized by products where the price elasticity of demand is more elastic.

The second panel illustrates how supply reverts back to equilibrium. Typically, farmers are not able to respond to a price increase immediately, as they need to breed additional animals, purchase additional equipment, or hire additional laborers to increase their supply. The degree to which farmers are able to increase their supply in the short term is summarized by the price elasticity of supply as measured over a given time period. Lower elasticity of supply means that farmers are slower to increase their supply such that it takes longer to nullify the supply reductions caused by the farm transition.

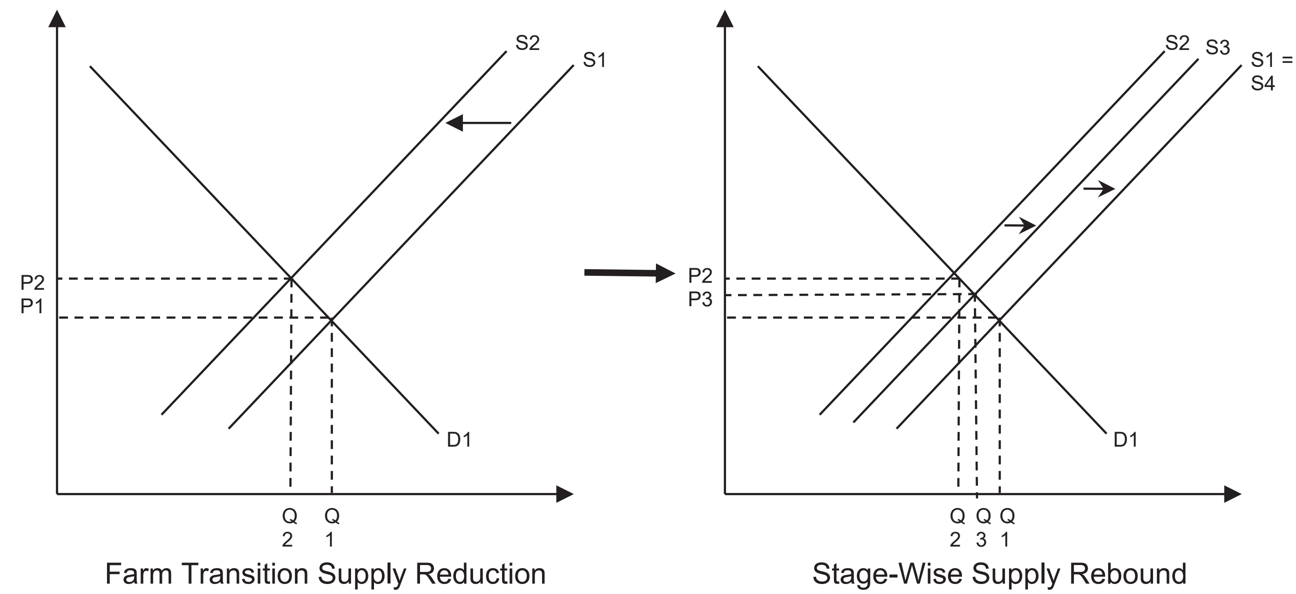
To demonstrate how to estimate leakage using supply and demand elasticities, we narrow our focus to the dairy industry, for which we have high-quality estimates for both measures. Using the price elasticity of demand of dairy from Tatiana Andreyeva et al.'s systematic review of food demand elasticities[82] and supply elasticity estimates from Marin Bozic et al.,[83] we model how supply responds over time to a 3% decrease in dairy supply in a given market. Our leakage modeling approach (Equation 9 in Appendix A)[84] finds that a dairy farm transition can expect a carbon reduction approximately equivalent to removing that dairy farm from the market for approximately three years.

However, we acknowledge that our modeling approach is imperfect, as it relies on the retail dairy demand elasticity as opposed to the farm gate elasticity. Further, the supply

Thesis, Purdue University), https://doczz.net/doc/7607389/effect-of-cooperatives-working-together-herd-retirements.

77. Dixon et al., *supra* note 69.
78. Press Release, National Milk Producers Federation, Cooperatives Working Together Settlement Lifts Legal Cloud (Dec. 4, 2019), https://www.nmpf.org/cooperatives-working-together-settlement-lifts-legal-cloud/.
79. Dixon et al., *supra* note 69.
80. McCay, *supra* note 76.
81. Samara Mendez & Jacob Peacock, *Milking It: Exploring the Impact of Plant-Based Milk in the US* (Humane League Labs, Report No. E019R02, 2021).
82. Tatiana Andreyeva et al., *The Impact of Food Prices on Consumption: A Systematic Review of Research on the Price Elasticity of Demand for Food*, 100 Am. J. Pub. Health 216 (2010).
83. Marin Bozic et al., *Tracing the Evolution of the Aggregate U.S. Milk Supply Elasticity Using a Herd Dynamics Model*, 43 Agric. Econ. 515 (2012).
84. Appendix A is available at https://www.eli.org/sites/default/files/files-pdf/Rutinel-Quaade-Appendices.pdf.

Figure 5. Stage-Wise Supply Rebound After a Farm Transition



elasticity we use is estimated by simulating the effects of a permanent 10% price increase, as opposed to a setting in which prices are flexible. We hope these leakage estimates continue to improve as better supply and demand elasticities become available.

1. Leakage and Demand Elasticity: Reform Opportunities

There are many factors that may increase the demand elasticity for animal products. One possible factor is the trend of plant-based alternatives increasingly becoming more accessible, cheaper, and tastier.[85] If plant-based alternatives to animal products are seen as true substitutes, then consumers will not be willing to pay higher prices for animal products when the quantity of the animal product is reduced. An analogous examination of this principle is the extent to which consumers have very strong cross-price elasticities for specific and highly substitutable products, such as whole milk with regard to other dairy products.[86]

In other words, if whole milk goes up in price, then consumers respond by significantly decreasing the quantity they demand, presumably substituting their consumption with similar varieties of dairy milk (e.g., 2% milk). In the context of milk, it seems reasonable to believe that consumers will begin to see plant-based alternatives to milk as viable substitutions to cow's milk as the plant-based products increasingly approximate cow's milk on metrics of accessibility, price, and taste. But there are other reasons that individuals and companies use cow's milk for their consumption and production, such as the production and consumption of cheese, ice cream, and yogurt. These products are enabled by the natural proteins found in milk (whey and casein), but many companies are also working on creating non-animal alternatives to these proteins.[87]

2. Cross-Price Elasticities Between Animal Products and Plant-Based Alternatives

Figure 6 (next page) demonstrates how cross-price substitution effects may occur with respect to livestock farm transitions that increase the production of plant-based products. This effect will be highly dependent on the cross-price substitution of animal products and their plant-based alternatives. A farm transition project would cause the supply curve for the livestock commodity to shift to the left and the supply curve for the human-edible plants to shift to the right. The decrease in price for the human-edible plants causes a cross-price substitution effect that shifts the demand curve for the livestock commodity to the left. Similarly, the increase in price that may result for the livestock commodity causes a cross-price substitution effect that shifts the demand curve for the human-edible plants to the right. Although the extent of these effects are ambiguous, quantities for livestock commodities should decrease while the quantities for human-edible plants should increase.

3. Supply Rebound Elasticity

In the same way that increasing the demand elasticity of animal products would decrease the leakage effects of farm transitions, decreasing the supply rebound elasticity val-

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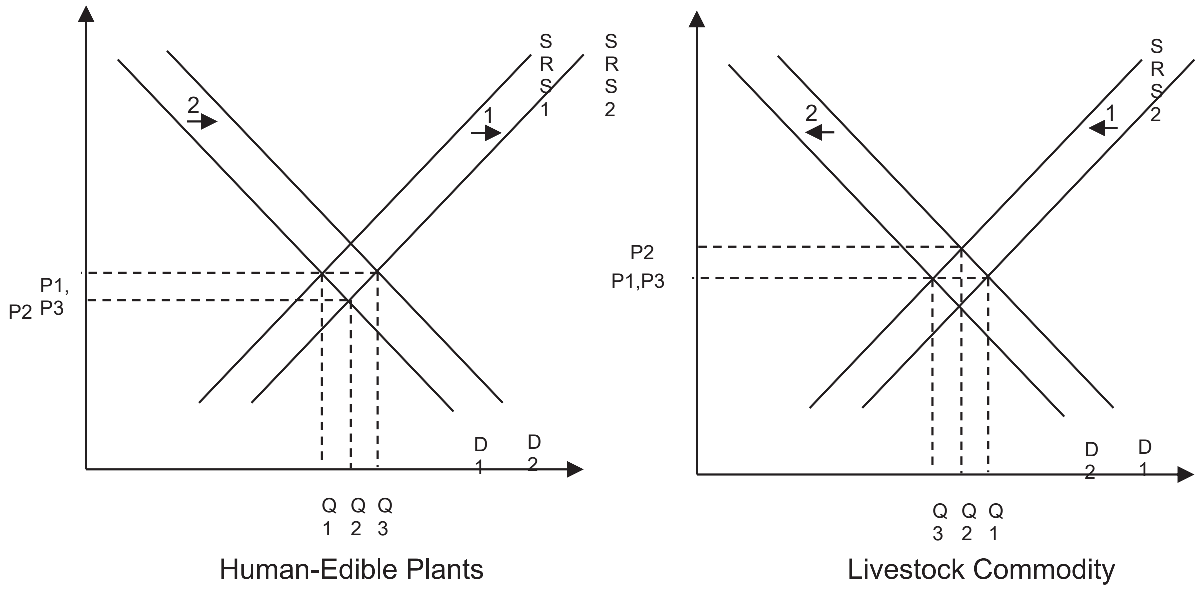
85. Julie Creswell, *Plant-Based Foods Expand, With Consumers Hungry for More*, N.Y. Times (Sept. 8, 2021), https://www.nytimes.com/2021/09/08/business/plant-based-food-companies.html.
86. Mendez & Peacock, *supra* note 81.
87. Good Food Institute, *Alternative Protein Company Database*, https://gfi.org/resource/alternative-protein-company-database/ (last visited Sept. 27, 2022).

Figure 6. Cross-Price Elasticity of Demand Between Animal Products and Plants



ues would also decrease the leakage effects. One analysis of herd supply elasticity found that larger CAFOs are less responsive to price changes than smaller CAFOs.[88] Perhaps this is because regulations become more stringent with increasing herd sizes.[89] Regardless of the reason, this may mean that supply rebound elasticities decrease over time as a greater proportion of the livestock industry consolidates into larger CAFOs.

Additionally, a decrease in the supply rebound effect may occur when livestock operations have to comply with additional regulations or permits to increase the size of their operation or begin a new operation. Further, placing a moratorium on the expansion or creation of new CAFOs, with bills such as the Farm System Reform Act,[90] may drive the supply rebound elasticity to zero, since still-functioning farms would not be able to increase their herds to compensate for the exogenous decrease in herds elsewhere.

F. Verifiable

For an offset project to be successful, it must be verifiable. A project's verifiability depends on whether well-developed methodologies are used to measure emissions for the project and its baseline and whether the project can be easily monitored. Fortunately, several universally accepted protocols already use the well-developed methodologies, formulas, and emission factors necessary for this protocol idea.[91] Additionally, this may be one of the easiest and least expensive protocols to monitor since removing livestock from an operation and replacing them with crops is such a conspicuous aspect of the project boundary that it can even be monitored using satellite imagery.

G. Permanent

Emission offsets come in two forms: reversible and nonreversible.[92] Reversible carbon emissions are reductions that may be re-released into the atmosphere in certain situations. For instance, a reforestation project could emit all of its sequestered carbon during a wildfire, so it is a reversible carbon offset. Nonreversible emissions are reductions in emissions relative to an assumed baseline. By transitioning farms from pollution-heavy animal farms to pollution-light cropland, the project aims to reduce emissions relative to an assumed baseline. As such, this protocol idea presents a nonreversible and permanent reduction in emissions.

H. Avoids Social and Environmental Harms and Promotes Co-Benefits

The final criterion for an offset credit protocol is to ensure its implementation avoids social and environmental harms. Beyond reductions in GHG emissions and avoiding harms, this protocol would create a tremendous number of co-benefits for farmers, animals, food security, workers' rights, public health, and environmental justice concerns. The subsections below outline the ways in which a farm transition protocol can help alleviate some of the social and environmental harms associated with our current food system.

88. Bozic et al., *supra* note 83.
89. Frank R. Spellman & Nancy E. Whiting, Environmental Management of Concentrated Animal Feeding Operations (CAFOs) ch. 2 (2007).
90. Farm System Reform Act of 2019, S. 3221, 116th Cong. (2019), https://www.congress.gov/bill/116th-congress/senate-bill/3221/text.
91. See, for example, CAR's Livestock Protocol, *supra* note 37, and Grassland Protocol, *supra* note 44.
92. Carbon Offset Guide, *Permanence*, https://www.offsetguide.org/high-quality-offsets/permanence/ (last visited Sept. 27, 2022).

1. Land, Water, and Local Air

Approximately 41% of U.S. land (nearly 800 million acres) is used to feed farmed animals.[93] Because animal production is intrinsically more resource-intensive than plant-based production, it requires much more clearing of forests and grasslands for cropland. If plant-based production is not appropriately incentivized, producing food for the world's growing population would clear an additional 540 million hectares of land from 2010 to 2050, releasing 600 million metric tons of CO_2e in the process.[94]

This clearing would also create tremendous repercussions for wildlife and species extinction.[95] Additionally, food production creates 32% of global terrestrial acidification, causing the soil to be unproductive for future use.[96] Animal agriculture is a drastically more potent source of terrestrial acidification than alternative, human-edible crops.[97]

The harms of animal agriculture to our water supply are twofold: contamination and depletion. When it rains, the fertilizers, pesticides, and animal waste on factory farms wash harmful nutrients, bacteria, and viruses into our waterways. As a result, animal agriculture produces significantly larger effects than plant-based agriculture on eutrophication, causing a significant amount of the excessive water nutrients that create harmful algal blooms and dead zones.[98] In the United States, animal farming is a leading source of contamination of rivers, streams, wetlands, estuaries, and groundwater.[99]

Our food system is also responsible for water depletion, driving 90% to 95% of global scarcity-weighted water use.[100] Animal farming requires large amounts of water for the animals themselves, the crops that the animals consume, and a series of other processing and sanitation measures. As a result, animal products require several magnitudes more water than other crop alternatives.[101] In the western United States, animal farming is the leading driver of water shortages.[102]

Many factory farms produce dangerous air pollutants that harm the health of nearby residents.[103] This air contamination can prove deadly. Animal agriculture is responsible for 80% of the air quality-related deaths from food production, resulting in 12,700 premature deaths every year in the United States alone.[104] Further, factory farms are disproportionately placed in communities of color, participating in a system of environmental racism.[105]

2. Farmer Exploitation

Low sale prices and high operating costs make profits and debt repayment for some livestock farmers increasingly difficult. As a result, animal farms are forced to shut down across the nation, but only after suffering through an uphill battle against market trends and large meat corporations for years. For instance, from 2012 to 2017, the number of dairy farms with sales dropped from 50,556 to 40,336.[106] Similar trends exist for eggs, poultry, and hogs.[107] Unfortunately, with seemingly no other options available to them, farms struggle through tumultuous years without profit before eventually going out of business, caught between tremendous debts and vanishing glimmers of hope. Figure 7 (next page) shows the possible debt life cycle that many farmers have to endure in their search for financial security.

To examine the difficulties of animal farming, let us take a brief look at poultry meat farming. Nearly all broiler chickens come from farmers operating as contract growers under large meat corporations.[108] Large meat corporations, such as Tyson, are known as "integrators." They control the farm's processes and directly own the feed, veterinary services, transportation, and even the animals themselves from the hatchery to the slaughterhouse. These poultry contract growers receive their pay based on a "tournament system" in which farmers receive compensation based on

93. Dave Merrill & Lauren Leatherby, *Here's How America Uses Its Land*, Bloomberg (July 31, 2018), https://www.bloomberg.com/graphics/2018-us-land-use/.
94. David Tilman & Michael Clark, *Global Diets Link Environmental Sustainability and Human Health*, 515 Nature 518 (2014), *available at* https://www.nature.com/articles/nature13959?source=post_page.
95. Pamela A. Matson et al., *Agricultural Intensification and Ecosystem Properties*, 277 Science 504 (1997), *available at* https://www.science.org/doi/abs/10.1126/science.277.5325.504.
96. Joseph Poore & Thomas Nemecek, *Reducing Food's Environmental Impacts Through Producers and Consumers*, 360 Science 987 (2018), *available at* https://www.science.org/doi/10.1126/science.aaq0216.
97. *Id.*
98. *Id.*
99. U.S. Environmental Protection Agency, *National Summary of State Information—Assessed Waters of United States*, https://downloads.regulations.gov/EPA-HQ-OW-2010-0222-0732/content.pdf (last updated Jan. 3, 2012).
100. Poore & Nemecek, *supra* note 96.
101. Tilman & Clark, *supra* note 94.
102. Brian D. Richter et al., *Water Scarcity and Fish Imperilment Driven by Beef Production*, 3 Nature Sustainability 319 (2020), *available at* https://www.nature.com/articles/s41893-020-0483-z.
103. Artis v. Murphy-Brown LLC, No. 7:14-CV-00237-BR (E.D.N.C. Nov. 8, 2017).
104. Nina G.G. Domingo et al., *Air Quality-Related Health Damages of Food*, 118 PNAS art. e2013637118 (2021).
105. Press Release, Earthjustice, EPA Must End Discrimination, Stop States From Permitting Polluters in Overburdened Communities of Color (July 15, 2015), https://earthjustice.org/news/press/2015/epa-must-end-discrimination-stop-states-from-permitting-polluters-in-overburdened-communities-of-color-0; Christine Ball-Blakely, *CAFOs: Plaguing North Carolina Communities of Color*, 18 Sustainable Dev. L. & Pol'y art. 3 (2017), *available at* https://digitalcommons.wcl.american.edu/cgi/viewcontent.cgi?article=1598&context=sdlp.
106. USDA National Agricultural Statistics Service, *Quick Stats*, https://quickstats.nass.usda.gov/results/8080B307-337D-3D75-9FB6-783FB7746115 (last visited Sept. 27, 2022).
107. Farmers specializing in each livestock category continues to decrease: National Agricultural Statistics Service, USDA, 2012 Census of Agriculture Highlights: Poultry and Egg Production (2015), https://www.nass.usda.gov/Publications/Highlights/2015/Poultry_and_Egg_Production.pdf; National Agricultural Statistics Service, USDA, 2012 Census of Agriculture Highlights: Hog and Pig Farming (2014), https://www.nass.usda.gov/Publications/Highlights/2014/Hog_and_Pig_Farming/Highlights_Hog_and_Pig_Farming.pdf; National Agricultural Statistics Service, USDA, 2017 Census of Agriculture Highlights: Poultry and Egg Production (2020), https://www.nass.usda.gov/Publications/Highlights/2020/census-poultry.pdf [hereinafter Poultry and Egg Production].
108. Poultry and Egg Production, *supra* note 107.

Figure 7. Farmer Debt Treadmill

Source: Adapted from *What Debt in Chicken Farming Says About American Agriculture,* RAFI (July 12, 2016), https://www.rafiusa.org/blog/what-debt-in-chicken-farming-says-about-american-agriculture/.

their performance compared to a set of farmers selected by the meat company.

Despite working long, arduous hours, many farmers have little to show for it. Farm bankruptcy rates remain high, and more than 90,000 farmers lost more than $50,000 in 2017 alone.[109] Farmers and farmworkers commit suicide at one of the highest rates of any occupation in the United States.[110]

Crops such as beans, nuts, fruits, and vegetables have the potential to bring higher net incomes with lower debt burdens.[111] Farmers need help making the transition into better opportunities, and a farm transition offset protocol appears to be a suitable option.

3. Labor Exploitation

Because animals are crammed by the thousands in confined spaces, laborers are forced to inhale an immense amount of harmful ammonia, hydrogen sulfide, and particulate matter made up of fecal matter, urine, animal dander, fungi, and bacterial toxins.[112] These conditions are known to cause a series of pulmonary and cardiovascular diseases.[113] Further, injury rates in factory farms and slaughterhouses are dramatic.[114]

Instead of raising the working standards, employers have sought to recruit workers who will simply accept lower standards. With such terrible working conditions, it is no wonder why such a high percentage of farm laborers are undocumented immigrants.[115] Shifting production toward plant-based agriculture will not be a panacea for farm laborers. Still, it would help these laborers avoid some of the worst aspects of working in the agricultural sector.

4. Animal Welfare

The drive for efficiency and minimal costs in animal agriculture come at the expense of the animals' well-being. The suffering forced onto farmed animals comes in three parts: the facilities in which they are raised, the selective breeding that alters their bodies, and standard mutilation and slaughter practices.

For an illustration of the conditions of factory-farmed animals, let us briefly examine the life of a poultry chicken. The United States produced more than nine billion broiler chickens in 2021.[116] A typical factory-farmed chicken receives between 0.64 and 0.8 square feet of space, barely enough room to fit their bodies, and not nearly enough

109. USDA National Agricultural Statistics Service, *Net Cash Farm Income of the Operations and Producers*, https://www.nass.usda.gov/Quick_Stats/CDQT/chapter/1/table/5/state/US/year/2017 (last visited Sept. 27, 2022).
110. Wendy Ringgenberg et al., *Trends and Characteristics of Occupational Suicide and Homicide in Farmers and Agriculture Workers, 1992-2010*, 34 J. Rural Health 246 (2018), *available at* https://onlinelibrary.wiley.com/doi/full/10.1111/jrh.12245.
111. USDA ERS, *Tailored Reports*, https://my.data.ers.usda.gov/arms/tailored-reports (last visited Sept. 27, 2022).
112. María Cambra-López et al., *Airborne Particulate Matter From Livestock Production Systems: A Review of an Air Pollution Problem*, 158 Env't Pollution 1 (2010).
113. CAFO Subcommittee of the Michigan Department of Environmental Quality Toxics Steering Group, Concentrated Animal Feedlot Operations (CAFOs) Chemicals Associated With Air Emissions (2006), http://www.michigan.gov/documents/CAFOs-Chemicals_Associated_with_Air_Emissions_5-10-06_158862_7.pdf.
114. Kenneth Culp et al., *Traumatic Injury Rates in Meatpacking Plant Workers*, 13 J. Agromedicine 7 (2008), *available at* https://doi.org/10.1080/10599240801985373.
115. USDA ERS, *Farm Labor*, https://www.ers.usda.gov/topics/farm-economy/farm-labor (last updated Mar. 15, 2022). These statistics do not include livestock workers, but there is no reason to believe the rates would be different among crop and livestock workers.
116. U.S. Poultry and Egg Association, *Economic Data—Poultry Production and Value 2021 Summary*, https://www.uspoultry.org/economic-data/ (last visited Sept. 27, 2022).

space to spread their wings without hitting other birds.[117] Nor does this space allow them to engage in their natural behaviors such as dust bathing.[118] Given their limited space, these chickens spend their lives sitting or standing in feces.[119] This causes them to breathe high levels of ammonia, which causes tracheal inflammation and infections.[120] Despite never allowing chickens to see any natural light, these facilities keep their lights on for nearly the entire day to promote constant eating.[121]

Much of the suffering is an inherent aspect of the chicken's body. Broiler chickens are bred to grow so large in such a short period that their bones break, and their ligaments tear under the pressure of their own weight.[122] Since 1957, corporations have bred modern-day chickens to grow more than four times as large in even less time.[123] Although some meat corporations proclaim they do not feed growth hormones to their animals, this obscures the fact that industrial agriculture uses selective breeding to create animals that have those additional hormones built in to their internal system. As a result of this unnatural growth, broiler chickens suffer heart attacks, congestive heart failure, and difficulty breathing, standing, and walking.[124]

The conditions briefly examined above are not exclusive to the life of poultry chickens. Dairy cows, cattle, hogs, and egg-laying hens also experience similar suffering.[125] In addition to promoting the interests of the environment, farmers, and laborers, it is imperative that a farm transition offset protocol emphasize animal welfare concerns. Therefore, the only supported offset projects should be those that specifically move farmers from raising animals to growing plants. Further, to better serve this goal and others, the farmer should grow crops intended for direct human consumption.

117. Chicken Check In, *Cage-Free: What Does Cage-Free Mean? Is It Better to Buy Cage-Free Chicken?*, https://www.chickencheck.in/faq/cage-free-chicken/ (last visited Sept. 27, 2022).
118. Ian J. Duncan, *Behavior and Behavioral Needs*, 77 Poultry Sci. 1766 (1998).
119. Nanthi S. Bolan et al., *Uses and Management of Poultry Litter*, 66 World's Poultry Sci. J. 673 (2010).
120. Ying Zhou et al., *The Alterations of Tracheal Microbiota and Inflammation Caused by Different Levels of Ammonia Exposure in Broiler Chickens*, 100 Poultry Sci. 685 (2021).
121. Karen Schwean-Lardner & Hank Classen, Ross Tech, Lighting for Broilers (2010), http://en.aviagen.com/assets/Uploads/RossTechLightingforBroilers.pdf.
122. Mi Yeon Shim et al., *The Effects of Growth Rate on Leg Morphology and Tibia Breaking Strength, Mineral Density, Mineral Content, and Bone Ash in Broilers*, 91 Poultry Sci. 1790 (2012).
123. Martin J. Zuidhof et al., *Growth, Efficiency, and Yield of Commercial Broilers From 1957, 1978, and 2005*, 93 Poultry Sci. 2970 (2014), *available at* https://pubmed.ncbi.nlm.nih.gov/25260522/.
124. Peter Stevenson, Compassion in World Farming, Leg and Heart Problems in Broiler Chickens (2003), https://www.animallaw.info/article/leg-and-heart-problems-broiler-chickens.
125. Humane Society of the United States, An HSUS Report: The Welfare of Animals in the Pig Industry (2010); Humane Society of the United States, An HSUS Report: The Welfare of Cows in the Dairy Industry, https://www.humanesociety.org/sites/default/files/docs/hsus-report-animal-welfare-cow-dairy-industry.pdf.

5. Pandemic Risks

The COVID-19 pandemic illuminates the disastrous effects zoonotic diseases can have on every facet of our society. Wildlife markets have received the blame for this particular outbreak, but factory farms across the globe already contain diseases with fatal consequences in the event of a spillover to humans. This phenomenon is not new. The Centers for Disease Control and Prevention (CDC) state that three out of four emerging infectious diseases in humans come from animals, and they infect millions of Americans every year.[126]

To prevent the animals from dying while confined in CAFOs, USDA and the Food and Drug Administration permit antibiotics on livestock operations.[127] However, the use of antibiotics on farms contributes to antibiotic resistance in humans, creating a significant public health crisis.[128] In conjunction with the growing rate of antibiotic resistance in humans, suppressed immune systems and cramped conditions for animals create the perfect storm for the next disease outbreak.[129]

This proposal hopes to decrease pandemic risks at their source by shifting agricultural production from animals to plant-based production.

6. Public Health and Food Insecurity

Our current agricultural system promotes unhealthy diets. Our food system is detrimental to developed and developing societies alike, with 800 million people going hungry while two billion people are overweight or obese.[130] Animal agriculture sits at the center of this divide, simultaneously decreasing the number of calories available on the market through its inherent inefficiencies while compacting the calories it produces in dense, unhealthy products. To nutritiously feed a growing population, we must shift our productive capacity from inefficient and excessive animal products to healthy plant-based options.

Food waste is a major problem in our current agricultural system. But one large aspect of food waste is entirely out of sight because it does not show up in the waste bin: the inefficiency of converting crops to edible animal products. To produce animal products, farmed animals must consume several times as many calories of crops as they will produce through their meat and byproducts. An ani-

126. CDC, *One Health: Zoonotic Diseases*, https://www.cdc.gov/onehealth/basics/zoonotic-diseases.html (last reviewed July 1, 2021).
127. Henrik C. Wegener, *Antibiotics in Animal Feed and Their Role in Resistance Development*, 6 Current Op. Microbiology 439 (2003).
128. Timothy F. Landers et al., *A Review of Antibiotic Use in Food Animals: Perspective, Policy, and Potential*, 127 Pub. Health Reps. 4 (2012), *available at* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3234384/.
129. Brad Spellberg et al., National Academy of Medicine, Antibiotic Resistance in Humans and Animals (2016).
130. Almut Arneth et al., *Summary for Policymakers*, *in* Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems 7 (Priyadarshi R. Shukla et al. eds., IPCC 2019).

mal's inherent biology causes the vast majority of these calories to be wasted as feces, heat, or inedible body parts.

For example, it takes up to 25 kg of feed to produce 1 kg of edible beef.[131] Even poultry converts only around 11% of gross feed energy into human food, according to the most comprehensive methods.[132] These wasted calories could otherwise feed hungry people worldwide. This waste does not show up in our garbage bin, but it should be counted and addressed nonetheless.

On the other hand, excessive consumption of animal products in wealthy societies leads to a series of chronic health conditions. The U.S. Department of Health and Human Services' (HHS') and USDA's 2015-2020 dietary guidelines state that American underconsumption of fruits, vegetables, and whole grains and overconsumption of meat, poultry, and eggs is a public health concern.[133] As a result, the standard American diet suffers from high rates of cancer, diabetes, and cardiovascular disease.

To combat this public health issue, the U.S. dietary guidelines recommend a shift from meats, poultry, eggs, and cheese to fruits, vegetables, whole grains, nuts, and seeds. The guidelines also recommend two other dietary styles—Mediterranean and vegetarian diets—that further emphasize plant-based foods. Globally, transitioning from animal products to plant-based alternatives will prevent millions of deaths from cardiovascular disease, cancer, and diabetes.[134]

III. Discussion and Conclusion

Our Article has proposed a carbon offset protocol and methodology for monetizing the carbon emission reductions achieved by farm transitions. We explain that it is possible to test for additionality by assessing whether livestock farmers have the liquidity to conduct farm transitions in the absence of carbon financing. Further, we provide guidelines for conservative accounting methodologies that account for potential market leakage to ensure the realness of accredited emissions reductions.

As the emissions reductions created by a farm transition are not likely to be emitted once again, we argue that our proposed carbon offset protocol meets a higher standard of reversibility than many other agricultural carbon offset protocols. Farm transitions are also capable of a number of environmental, social, health, and animal welfare co-benefits. As such, we believe farm transitions to be a carbon offset opportunity of notable promise.

While financing remains a constraint for many farmers, a number of completed or ongoing farm transitions, such as those of Mike Weaver[135] and the Halley Farm,[136] inspire our carbon offset protocol proposal. Our hope is that incorporating farm transitions into carbon offset methodologies will unlock farm transitions for many more who currently do not have the means to undertake them.

Although farm transitions show great promise for offsetting carbon emissions, we do acknowledge a number of limitations. First, while our current knowledge base supports making conservative estimates of the emissions reductions for the dairy sector, these estimates would ideally be improved and verified using alternative methods. Additionally, obtaining better empirical estimates of price elasticities beyond the dairy sector would allow for rigorous estimations of leakage from transitioning other types of livestock operations.

Second, local market conditions not captured by the elasticity-based approach may substantially affect the extent of leakage. For instance, the fact that many animal-growing operations are required to be within close proximity to hatching, slaughter, or processing operations may cause slower market adjustments if multiple farmers transition within the same region.

There is still much room for research on the effects that ubiquitous plant-based alternatives to animal products will have on the demand elasticity of the animal product. Although it seems like a safe assumption to assume that improvements in the taste, convenience, and price of these alternatives will cause the demand elasticities of the animal products to increase, it is important to do deeper research to understand the extent of these effects. As demonstrated previously, as demand elasticities of livestock products increase, the emission reduction value of a farm transition increases since leakage effects are subdued.

Thus, it is likely that a farm transition protocol will become increasingly valuable as plant-based alternatives improve. Other factors that may influence the demand elasticity of animal products, such as increasing social stigma or rising incomes, should also be considered. Ultimately, however, what matters to leakage will be the demand elasticity at the time that the project is conducted, but these trends help us understand how elasticities have shifted over time and whether contemporary elasticity values should be trusted over historical averages.

More research should also be done on the factors that affect supply rebound elasticities—particularly research on how supply rebound elasticities differ based on region, with special attention to the role that CAFO regulations, moratoria, or restrictions play in the speed of supply rebound. Depending on the strength of these effects, a farm transition project developer may benefit from slower leakage by targeting certain regions that respond more slowly to exogenous herd reductions.

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131. *Facts and Figures*, *supra* note 16.
132. Tim Searchinger et al., World Resources Institute, Creating a Sustainable Food Future: A Menu of Solutions to Feed Nearly 10 Billion People by 2050 (2019).
133. HHS & USDA, 2015-2020 Dietary Guidelines for Americans (8th ed. 2015), https://health.gov/sites/default/files/2019-09/2015-2020_Dietary_Guidelines.pdf.
134. Willett et al., *supra* note 4.
135. Transfarmation Project, *Mike Weaver Turned His Chicken Farm Into a Hemp Farm*, https://thetransfarmationproject.org/other-farmers/mike-weaver-turned-his-chicken-farm-into-a-hemp-farm/ (last visited Sept. 27, 2022).
136. Transfarmation Project, *Halley Farm's Chicken-to-Hemp Successful Transfarmation*, https://thetransfarmationproject.org/our-farmers/halley-farms-successful-chicken-to-hemp-transfarmation/ (last visited Sept. 27, 2022).