Investing in the Future:

Building on Efficiency to Create a Resilient U.S. Beef Sector

Environmental Defense Fund

Contents

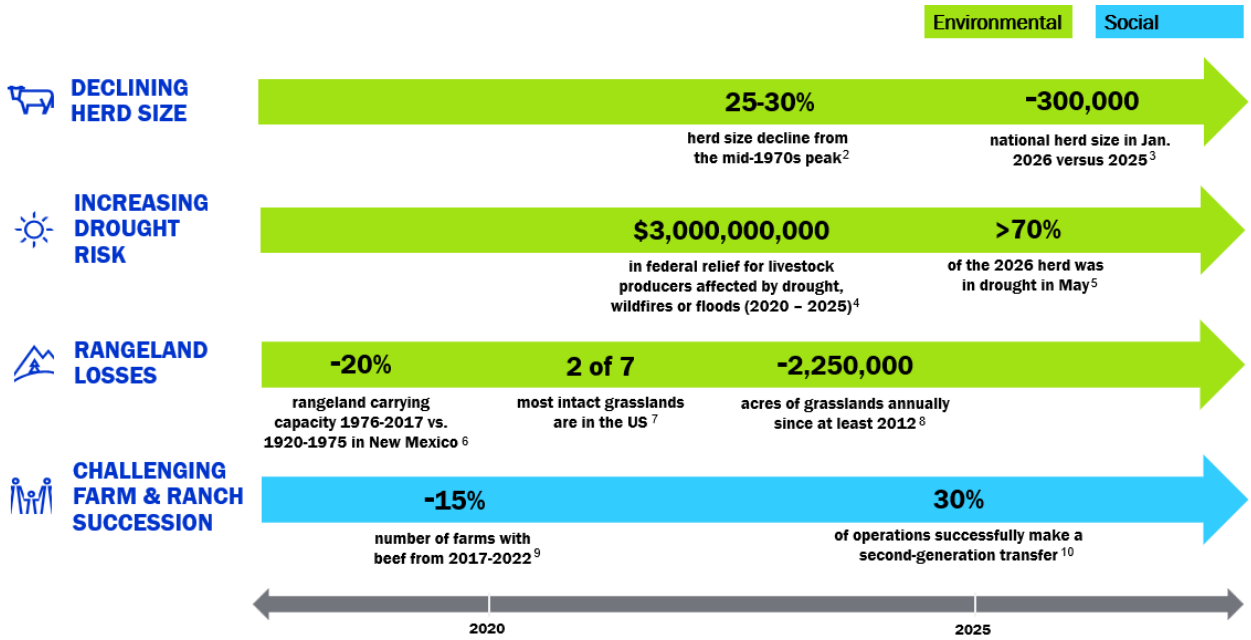
EXECUTIVE SUMMARY

Through innovation and coordination across a fragmented value chain, the U.S. beef industry has become highly efficient and productive. It converts capital, human labor, genetics, and land, soil, water and nutrients into safe, consistent products at scale, contributing to rural economies and the global food supply. These core inputs are essential to production, key to managing sectoral impacts, and increasingly affected by shocks in the system. Amid growing disruptions, beef valuation continues to rise, and consumer demand remains high.[1]

Progress to date has not been linear. Instead, it has leaped forward over the decades through a series of industry-wide paradigm shifts that aligned incentives and mandates, strengthened information flows, and established shared accountability across the system. Over the past 50 years, four major transformations have reshaped how the industry operates: premium value branded beef (Certified Angus Beef, CAB), industry practice standards (Beef Quality Assurance, BQA), prevention-based food safety (Hazard Analysis Critical Control Point, HACCP), and animal welfare auditing and verification. Each shift followed a common pattern: a clear industry threat or opportunity, pre-competitive collaboration, and redefinition of performance expectations. These shifts established the conditions for highly efficient production and growth.

System-level change is once again *necessary and with greater urgency than ever before*. The pressures the beef industry increasingly faces across environmental volatility, workforce instability, resource constraints, and tightening margins are not temporary disruptions.

Figure 1: Compounding social and environmental disruptions



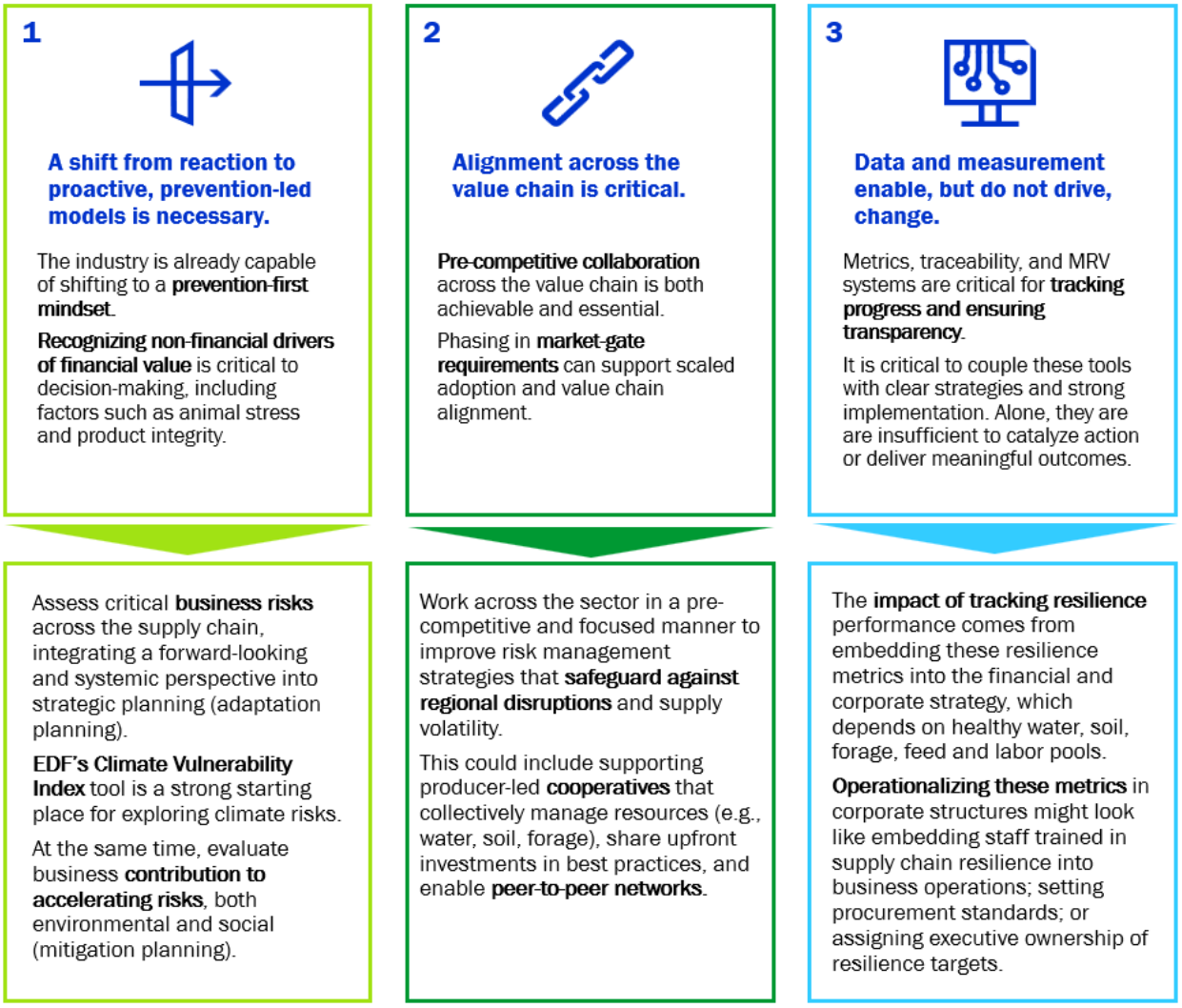
These are structural shifts. These compounding forces are exposing a critical vulnerability: an industry optimized for efficiency under stable conditions is not yet resilient enough in the face of increasing instability driven by multiple, overlapping disruptions. Navigating this moment requires, yet again, pre-competitive collaboration, clarity, and commitment.

This is a pivotal moment for leaders across the value chain. A more durable and sustainable U.S. beef value chain in the 21st century requires a paradigm shift towards resilience amid rapidly accelerating instability. Resilience is defined as: The system's ability to withstand, adapt to, or transform in the face of complex disruptions. Coupling resilience efforts with preventative mitigation measures to reduce future disruptions creates a powerful combination that can position the sector to better weather disruptions and find stability in a less predictable environment.

Resilience requires shoring up the foundation that the beef value chain relies on: strong communities and labor pools as well as healthy natural resources, ecosystems and herds. This requires both adapting to, and mitigating against, record droughts, extreme weather, and wildfires, among other disruptions. It is both improving physical capacities throughout the value chain and improving organizational and interpersonal capacity to work pre-competitively towards system-wide benefit.

History shows us that system level change is possible. It also gives us strategies for successful paradigm shifts.

Figure 2: Strategic insights from historic paradigm shifts, and example modern interventions



This white paper explores the strategies that built the current, highly efficient beef system, and how they can be applied today to support the U.S. beef sector becoming one of the most resilient in the world. These historic strategies have supported critical shifts in the beef sector in recent decades, offering clear evidence that they are achievable, impactful, and can be leveraged today to overcome the challenges the sector faces.

U.S. BEEF INDUSTRY AT A GLANCE

Beef production remains a major player in U.S. agriculture and rural economic activity. In 2024, cattle production generated roughly $113 billion in revenue, or about 22% of all U.S. agricultural cash receipts, making it the largest contributor to farm revenues of any commodity.[11]

At its foundation, it is a uniquely distributed production base. The U.S. cattle sector includes more than 730,000 operations, many of which are family operations, managing approximately 87 million head of cattle,[12] with ~90% of herds having fewer than 100 head.[13] This decentralized network raises cattle across diverse landscapes and climates, while historically maintaining a steady flow of cattle into downstream feeding and processing systems, where operations become less diffuse.

Feedlots deliver the efficiencies that come with operating at large scale: feedlots with capacities above 1,000 head account for roughly 85% of fed cattle production.[14] The processing sector then converts cattle into consumer-ready products, which are distributed to retailers, foodservice operators, and international buyers through large packing facilities. The U.S. meat and poultry processing industry employs hundreds of thousands of workers, who form the backbone of the national protein supply chain.

The industry sees high, sustained demand. In 2024, U.S. fresh beef retail sales exceeded $40 billion, accounting for more than half of the fresh meat market.[15] Producers, feeders,

and processors have responded by expanding product offerings from ground beef and everyday retail cuts to premium, branded, and specialty programs, to meet demand by American consumers, contributing to the United States' position as the world's largest producer and consumer of beef by volume.

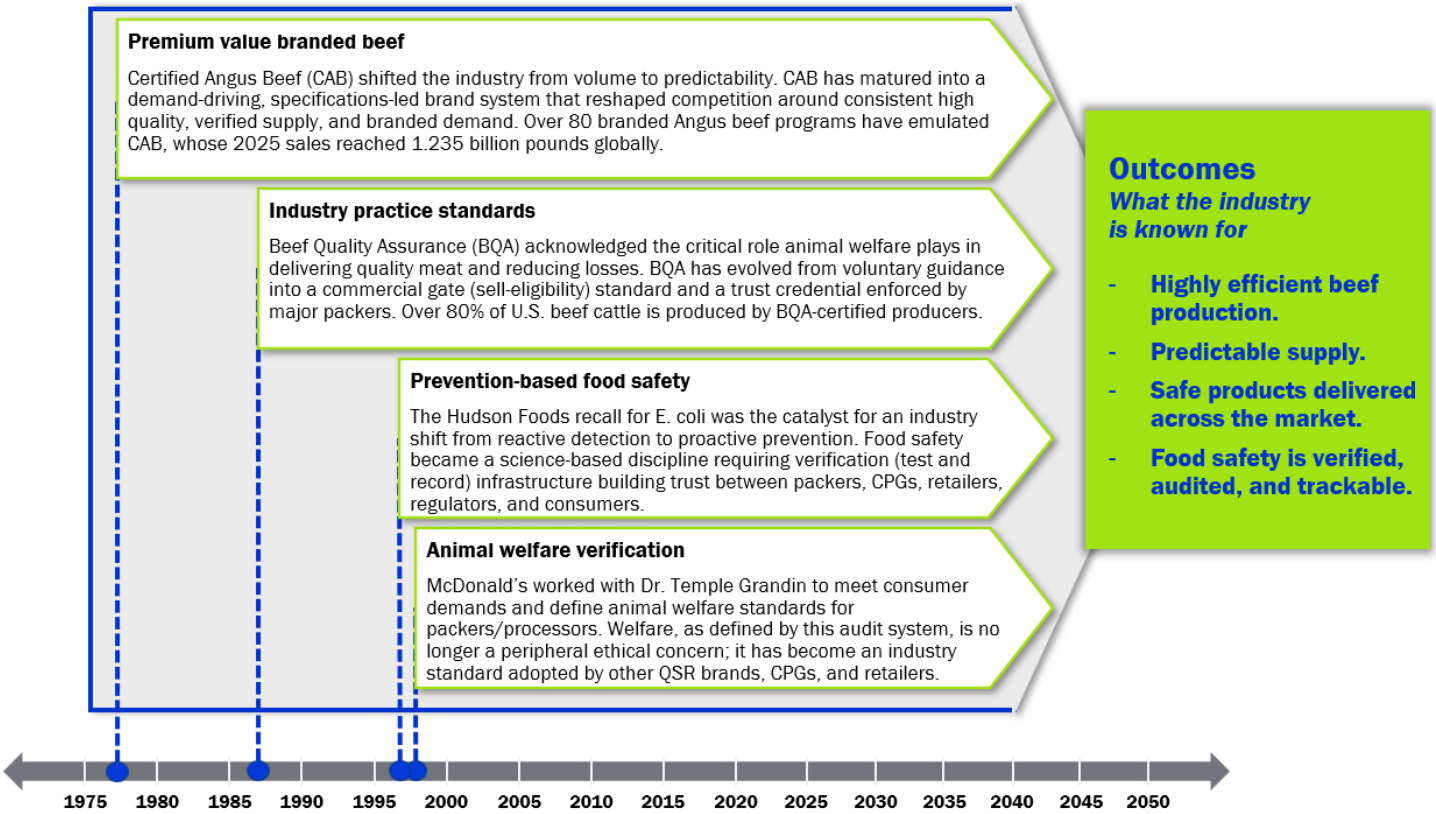
HISTORIC PARADIGM SHIFTS IN THE U.S. BEEF SECTOR

How the U.S. beef industry has changed over time

Spanning family-run cow-calf operations, large-scale feedlots, and processing facilities, the U.S. beef industry has built a highly efficient and productive livestock system. At its foundation, the industry has a production network capable of reliably converting land, capital, feed, and genetics into products for domestic and international markets. This is made possible by an ecosystem of jobs and services across ranching, feed production, animal health, transportation, processing, and food service.

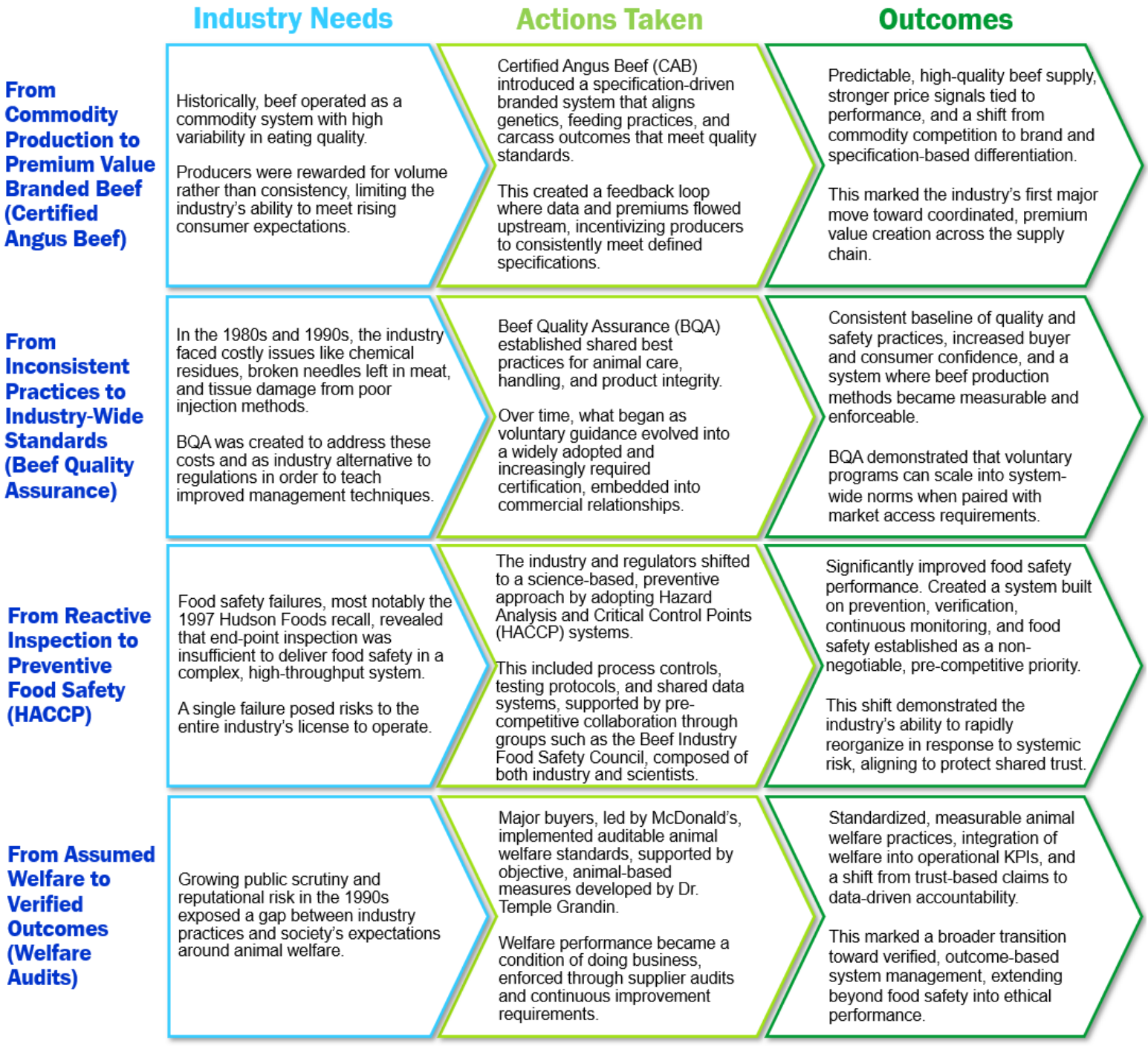
The sector today is the result of five decades of adapting, aligning, and improving in response to evolving market demands, consumer expectations, and systemic risks. Large-scale shifts were not incremental but step changes in system operations and performance. While the system-wide coordination they took may have just looked like the market doing its work, underneath that umbrella was substantive value chain alignment across a fragmented upstream and competitive downstream value chain.

Figure 3: Four major U.S. beef paradigm shifts



Each paradigm shift transformation followed a similar pattern: a clear industry need, a set of aligned, pre-competitive actions across the value chain, and durable outcomes that redefined performance.

Figure 4: Industry needs, actions, and outcomes of four major U.S. beef paradigm shifts



Taken together, these shifts illustrate a consistent pattern: the industry advances when clear signals, aligned incentives, and shared accountability mechanisms are established across the value chain. The result is a system that delivers outcomes through collective action that overcomes fragmentation and competition.

These historical paradigm shifts provide a roadmap for future progress. They demonstrate that when the industry aligns around a shared need, it can build the infrastructure, incentives, and feedback loops required to deliver system-wide progress.

The U.S. beef industry has reached a pivotal moment. The pressures it now faces across environmental volatility, workforce instability, resource constraints, and tightening margins are not temporary disruptions. They are structural shifts that require a similar level of coordination, clarity, and commitment.

MAINTAINING AND ADVANCING PROGRESS IN THE 21ST CENTURY

Emerging 21st-century operating conditions differ fundamentally from those that shaped the industry's current structure.

While the industry continues to evolve, recent changes have largely been reactive to emerging pressures rather than aligned, system-wide redesigns. This results in compounding challenges, spanning poor forage growing conditions to workforce instability. Reactive action 20, or even 10, years from now will be unable to resolve many of the compounding disruptions and crises explored below. Maintaining current gains and enabling continuous improvement requires proactive action.

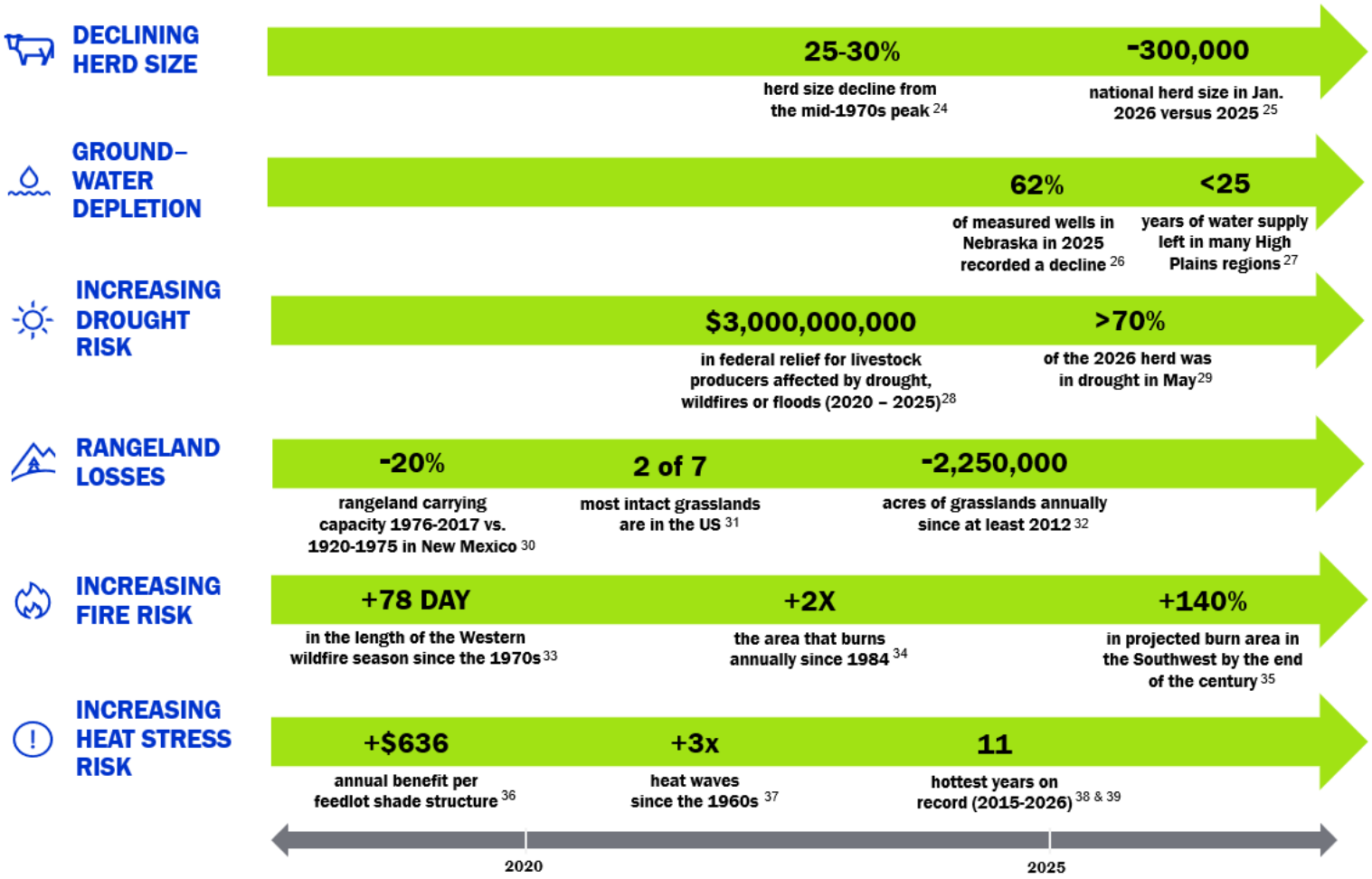
The structural pressures facing the industry are already visible and intensifying. Despite being one of the most efficient beef producers globally, prolonged drought, floods and wildfires, volatile extreme weather, and high operating costs have contributed to declining herd size and the U.S. beef supply dropping to levels not seen since the 1950s.[16] This increases the risk of lost market share and increased reliance on imports.

It is also a trend likely to continue. The U.S. beef system is reliant on water-constrained geographies such as the Southern Plains where communities, feed, cattle, and increasingly, data centers[17] (over)draw from the same limited resource base. For example, the High Plains Ogallala aquifer spans roughly 225,000 square miles across eight states. This region has produced one-fifth or $20 billion of U.S. agricultural output, but many areas lack sufficient water to supply the next 25 years.[18] In Nebraska, where 90% of the state sits atop the Ogallala, 62% of measured wells in Nebraska recorded a decline in 2025.[19] Much of Nebraska experienced some level of drought for most of the preceding six years.[20] Drought is no longer an episodic disruption but a consistent and powerful force driving repeated cycles of herd liquidation. In May 2026, over 70% of the total beef herd was impacted by

drought,[21] reducing near-term supply and long-term rebuilding capacity. Drought levels this early in the season have occurred less than 2% of the time in the history of the Drought Monitor.[22]

Meanwhile, rangeland carrying capacity is expected to continue to decline. New Mexico statewide data collected from 1920 onward found livestock carrying capacity was 20% lower in the 1976–2017 period compared to 1920–1975.[23] Shrub encroachment and climate change (more frequent heat and drought) have been primary drivers since the 1970s. In other areas, rangeland is lost to oil and gas development and pollution, urban development, and woody encroachment.

Figure 5: Compounding environmental crises for the U.S. beef system



Shocks are also coming from smoke and heat. Wildfire risk and smoke damage to people and animals alike has increased as the wildfire season has expanded by 78 days since 1970.[40] Since 1984, the area that burns annually has doubled.[41] Heat waves are now three times more frequent than ~60 years ago.[42] Heat waves have created mass mortality events in feedlots, while heat stress reduces performance of both forage and livestock. Heat stress just prior to slaughter triggers muscle glycogen breakdown, causing meat to become pale, mushy, and prone to moisture loss. Meanwhile, prolonged, chronic heat stress and wildfire smoke stress reduces muscle glycogen reserves, producing lower quality dry, dark, and firm meat. Heat and smoke-driven oxidative damage that degrades the quality of the proteins also shortens meat shelf life and compromises food safety by making meat more susceptible to bacterial growth and spoilage.[43] As these stressors accelerate, the costs in animal performance and meat quality losses can be expected to mount.

Individually, each of these pressures might be manageable. Together, they trap the industry in compounding shocks. Feed supply disruptions, shrinking herds, water scarcity, and heat stress are no longer isolated, but increasingly occurring simultaneously. This convergence exposes a core structural weakness: the system has been optimized for efficiency under 20th century conditions that included market swings, but not multiple, overlapping environmental and social disruptions at this level. As just one example, almost three billion dollars was approved for 2020 through 2025 as emergency relief payments to livestock producers suffering losses due to drought, wildfires, or flooding.[44]

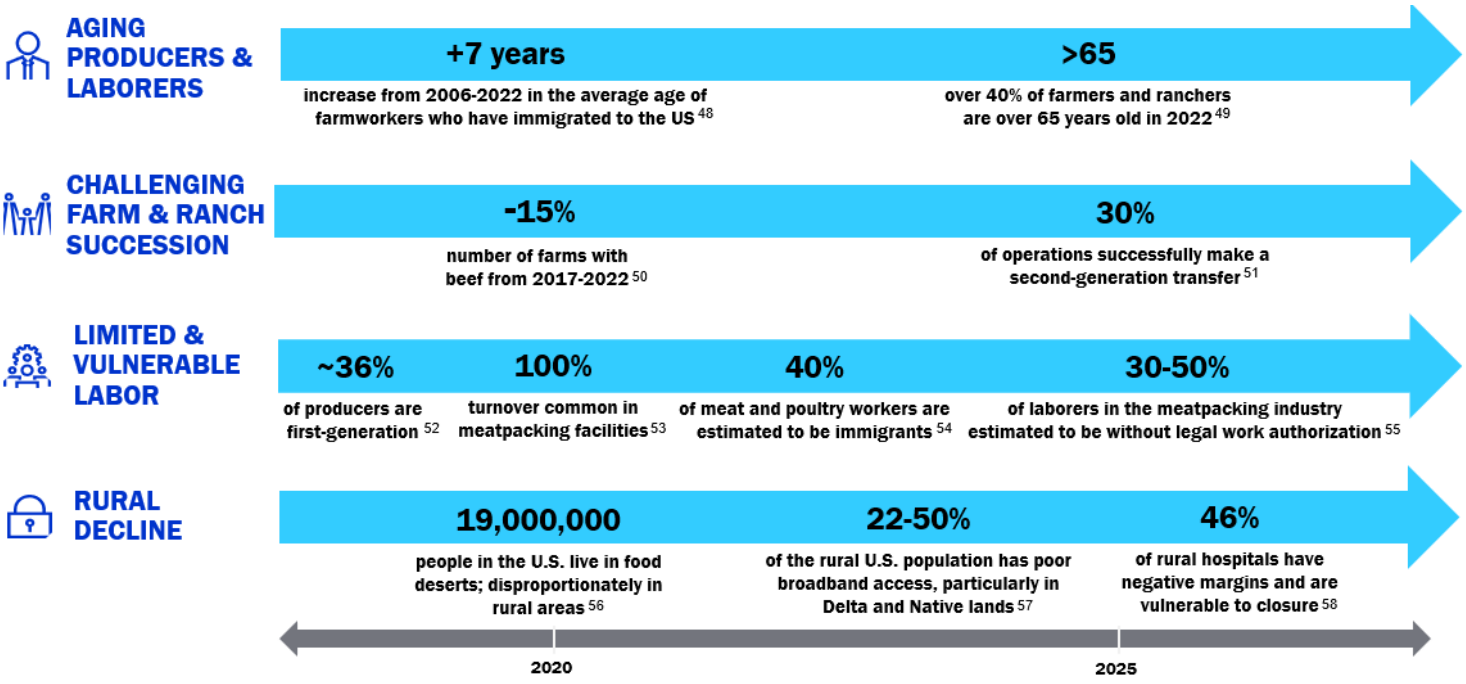
While these safety nets provide critical support, they are not a solution for safeguarding the beef value chain and the communities it operates in. As these pressures intensify, there is an urgent need for an aligned, industry-level response that addresses both their symptoms and root causes.

Environmental pressures are directly reshaping the industry's economic and social foundations. As extreme weather increases, it amplifies existing structural weaknesses in labor, succession, and industry organization, turning long-standing challenges into more immediate and material risks. Previously manageable constraints are now being accelerated and compounded by shocks and stressors, tightening margins and reducing the industry's ability to adapt. The result is an intersection of environmental and social pressures redefining how and where the industry can operate. This convergence shifts risk from isolated pressures to system-wide vulnerability and instability.

The sector remains heavily dependent on aging, family-owned operations. The next 20 years will see a transfer of 70% of all U.S. farmland. This transition period is precarious, as family farms struggle to endure; just 30% make it to the second generation, while only 12% survive to the third.[45] Succession is further strained by declines in rural infrastructure, rising operating costs, and new challenges such as skyrocketing farm and home insurance premiums, coverage rollbacks and even threats to the stability of the insurance industry

itself. As one example of the increasingly fragile ecosystem that supports agricultural stability, in 2024 the Farm Bureau Mutual Insurance Company of Arkansas had its balance sheet assessment moved down to fair and then down to adequate because of claims paid out after record May storms.[46] Since 2021, insurers have canceled at least 1.4 million policies and at least 36 insurers in seven states have announced plans to pause writing new policies or exit state markets. Insurers attributed more than one in four rate hikes, cancellations, and halts on new business to extreme weather or climate disasters.[47]

Figure 6: Compounding social crises in the U.S. beef system



Within the beef value chain, downstream consolidation has delivered efficiency gains, but it has also introduced single points of failure and reduced system flexibility. A single plant closure affects entire regions. Consolidation can also magnify supply bottlenecks creating livestock backlogs and driving sharp increases in processing costs nationwide. For example, during ~2017–2020 the industry experienced tight processing capacity and high utilization as the national cattle herd peaked, and slaughter-ready supply exceeded available shackle space. In 2019, a fire closed a packing plant in Kansas that handled ~6% of national beef supply.[59] Wholesale beef prices were trending downwards prior to the fire. Over the next two weeks, wholesale prices rose by ~10%.[60]

Labor is an equally critical constraint: processing and feedlot operations rely on a workforce that is both policy sensitive and variable; 40% of meat and poultry workers are estimated to have immigrated to the United States.[61] Especially vulnerable are laborers without legal

work authorization, estimated at 30-50% of meatpacking laborers.[62] Despite rising packer/processor wage pressures, especially post-COVID, it's not uncommon for meatpacking plants to rehire an entire workforce annually.[63]

Compounding shocks and overall increases in input costs, including insurance, water and labor, are tightening margins across the system. While valuable, efficiency gains alone are limited in their ability to address the major social and environmental challenges confronting the system. These challenges may make future efficiency gains harder to achieve and more capital-intensive.

Together, these trends point to a system under strain. Maintaining performance and delivering future resilience will require a new, coordinated paradigm shift addressing root-cause crises alongside symptom treatment.

BUILDING ON EFFICIENCY TOWARD RESILIENCE

Systemic innovation: Securing the beef value chain requires proactive action

The exploration in the following sections is grounded in EDF's U.S. beef dynamic systems analysis informed by extensive interviews across the U.S. beef sector. The intention is not a perfect solution, but a starting point for dialogue.

The 4 paradigm shifts explored above clearly show that major and even rapid systemic changes are possible in the U.S. beef industry. Securing the beef value chain, and the livelihoods it provides, requires the courage to see the path ahead and take proactive steps. Successfully navigating these compounding crises requires proactive action because natural ecosystems are on 50 to 100+ year timelines, and communities are on 5 to 15-year timelines. At current use rates, much of the Ogolla Aquifer is expected to be drained within the century;[64] a daunting reality that can be avoided by action today.[65]

A shift to proactive action has international momentum with other beef-producing regions increasingly seeking to lead in resilience by leveraging system-level innovation. Australia, for example, has mobilized a coordinated, industry-wide effort to strengthen the long-term durability of production. The Australian beef industry has set a national roadmap and supported it with investment in producer tools, measurement, and research and development. The approach incorporates efforts that support adaptation, like improving pasture and soil performance in drought-prone systems, as well as mitigation, such as advancing cattle genetics, feed efficiency, and supporting emerging technologies like feed supplements.[66] This effort is supported by national research bodies and the government, with a focus on maintaining competitiveness under increasing environmental constraints through proactive management.

Australia has also recognized that capturing the full value of this shift depends not only on implementing these changes, but on how they are communicated and received by global markets, policymakers, and the public. As environmental and operational pressures intensify, clearly demonstrating progress, linking resilience-building actions to broader system stability, and signaling where additional support is needed are critical to maintaining competitiveness, building trust, and delivering outcomes.

The U.S. beef industry also has a powerful opportunity to transparently share the social and environmental constraints it faces and coalesce support around the strong actions needed to respond. Moving forward, focusing on verified tracking of these operational headwinds and actions taken to address them is key to maintaining license to operate and managing risk. Proactive benchmarking of challenges as well as mitigation and adaptation measures being taken could support an understanding of high prices that reflect the true cost of managing climate disruptions and moving toward resilience in a challenging environment. Operational improvements should be deployed in parallel with transparent communication

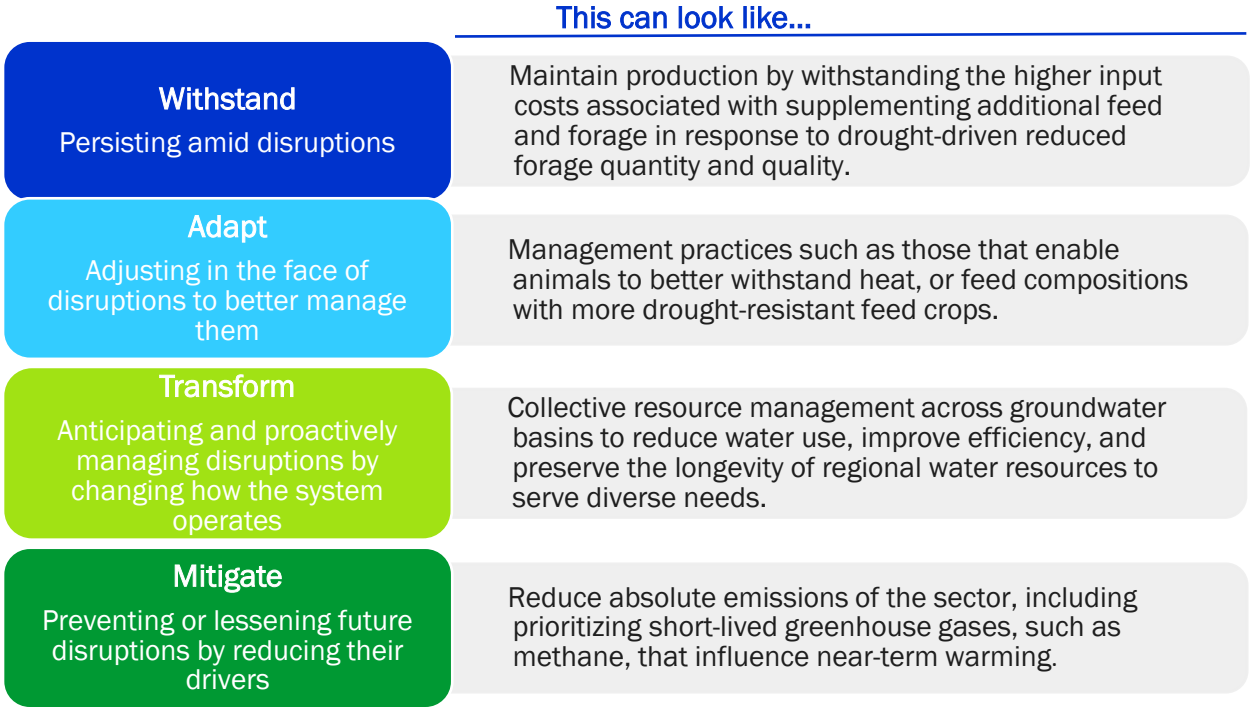
that demonstrates how the sector is responding in the face of these headwinds to foster greater industry and neighboring community resilience.

Supporting agricultural vitality by coupling resilience & mitigation measures

Resilience requires shoring up the foundation that the beef value chain relies on: strong communities and labor pools, healthy natural ecosystems, resources and herds. This requires both adapting to, and mitigating against, record droughts, flooding, extreme weather and wildfires. It requires both improving physical capacities throughout the value chain and improving organizational and interpersonal capacity to work pre-competitively towards system-wide benefit.

Resilience has become a widely used term. For the purposes of this report, **resilience is defined as:** The system's ability to withstand, adapt to, or transform in the face of complex disruptions, whether socioeconomic or biophysical. Agricultural vitality can be further strengthened and safeguarded when resilience is paired with emissions mitigation measures, which may reduce the severity of future disruptions by addressing root-cause drivers.

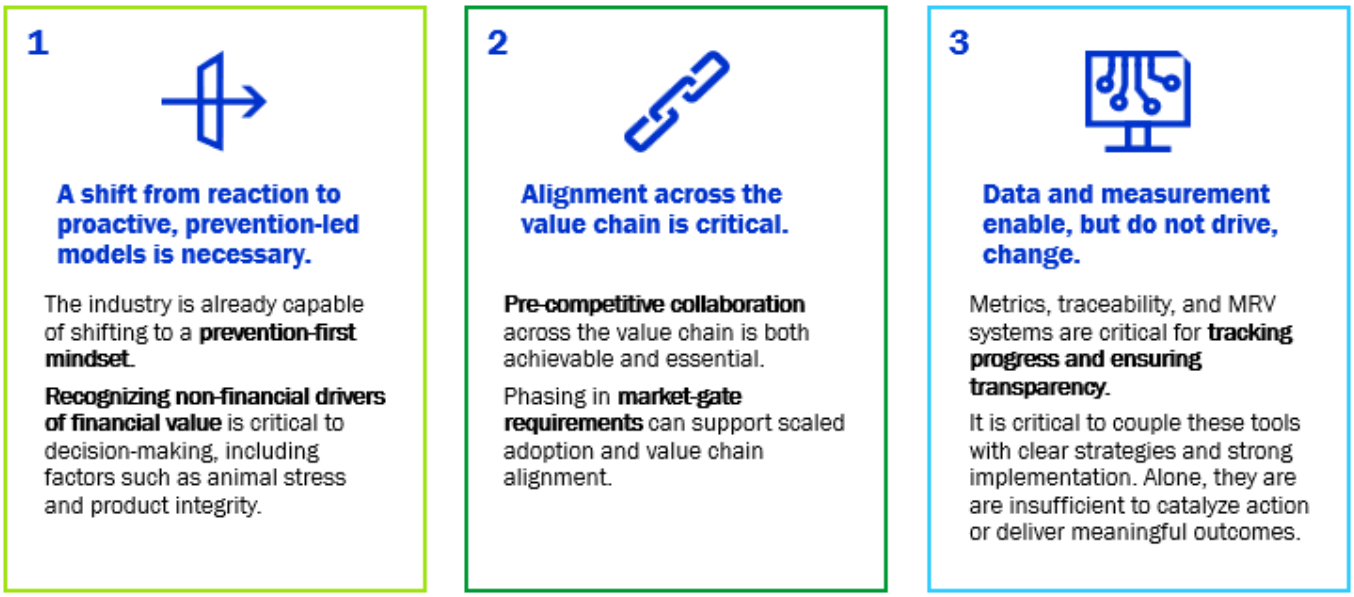
Figure 7: Defining beef system resilience



A resilience paradigm shift, strategic insights from 4 historic paradigm shifts

The recommended approaches below are 21st-century versions of steps taken during the four major 20th-century paradigm shifts. History shows that they are achievable. The 20th-century shifts made U.S. beef the most efficient in the world. 21st-century shifts can make it highly resilient by protecting physical assets (cattle and infrastructure), resources (water, land, soil, biodiversity), and people (owner/operators, labor, rural communities) – all of which are foundational to maintaining strong profits. By expanding the paradigm from a focus on increasing per-unit output to building system-wide resilience, the industry can address core drivers of instability. In doing so, it can better manage critical business risks and capitalize on new value creation opportunities.

Figure 8: Strategic insights from past paradigm shifts



Exploring the strategies used to execute on 20th century paradigm shifts reveal strong opportunities for critical 21st century transformation

HISTORIC PARADIGM SHIFT EXAMPLES		PARADIGM SHIFT STRATEGIES APPLIED TO RESILIENCE	TACTICAL EXAMPLES OF RESILIENCE ACTIONS
THE FOUNDATION			
Food safety: Shifted from reactive crisis management to a preventive identify-and-control approach to foodborne risk. **BQA**: Reduced quality and quantity of meat losses by preventing injection site lesions, bruising, and handling-related damage.	**From reaction to prevention**	**Preventing shocks** Shift from reacting to shocks (labor shortages/rural decline, extreme weather, increasing pests and disease) to proactively building resilience.	Assess business risks across the supply chain, integrating a forward-looking and systemic perspective into strategic planning (adaptation planning). In parallel, evaluate business contribution to accelerating risks, both environmental and social (mitigation planning). EDF's Climate Vulnerability Index is a strong tool for exploring climate risks.
ECONOMICS & MARKET VALUE			
Food safety: Recognized product safety as a baseline requirement for market access. **CAB**: Early recognition that high marbling and breed traits could become drivers of premium prices. **BQA**: Recognized that animal health and handling practices directly impact product quality and economic outcome. **Welfare**: Recognized that humane handling directly impacts yield and consumer trust.	**Recognize the non-financial creators of financial value**	**Holistic drivers of financial value** Recognize social wellbeing (labor, rural communities) and ecological health (water, soil, forage) as foundational to short, medium, and long-term economic performance. Based on the supply chain risks identified, strengthen social and environmental foundations through practical actions.	Downstream companies can send demand signals which reward and select for actions that enhance soil health and water availability. On the social side, engage early and often with rural and urban communities that both host beef facilities and provide labor for beef operations to proactively address, for example, health hazards. Ground engagement in transparent processes that show how input will inform decisions and ensure community feedback is consistently integrated.
CAB: Shifted from commodity beef to a differentiated, premium branded product. **BQA**: Established a "quality assured" category to differentiate compliant producers. **Welfare**: Differentiated products through verified animal welfare standards.	**Market differentiation**	**Resilience-driven differentiation** Develop resilience-linked offerings as non-commodity products marketed to both downstream brands and/or consumers.	Integrate resilience metrics that can be rewarded by downstream procurement; successful approaches to yield and carcass grading are a reference. Focus metrics on key risks, outcomes, and bioregional considerations to tie them to tangible reductions in business risk and supply disruptions as well as progress toward targets where relevant. See below on actionable MRV. Explore opportunities for resilience premiums or other contract benefits that could cover implementation costs. Premiums could be jointly shared by consumers, downstream brands and potential government subsidies.

PRE-COMPETITIVE ALIGNMENT

Food safety: Established industry coalitions to define science-based standards and enable data sharing.

CAB: Centralized coordination across the value chain through the American Angus Association.

Welfare: Enabled collaboration between retailers and packers to standardize mandated audit protocols and share cost of compliance.

Pre-competitive value chain collaboration

Shared adoption

Engage across and beyond the value chain to co-design strategies and drive scaled adoption of known practices that meaningfully shift social and environmental risk profiles in key sourcing bioregions.

Leverage shared ROI mechanisms and shared support. Incorporate appropriate mandates to drive coordinated action.

Organize coalitions around groundwater basins or watersheds, for example, to drive shared ROI effectively addressing increasing water scarcity and drought.

Similarly, work across the sector in a pre-competitive and focused manner to improve risk management strategies that safeguard against regional disruptions and supply volatility.

Support producer-led cooperatives that collectively manage resources (e.g., water, soil, forage), share upfront investments in best practices with strong ROI, and can create networks for peer-to-peer learning.

CAPACITY BUILDING

Food safety: Targeted research into pathogen reduction technologies (e.g., carcass washes).

CAB: Genetic research to define and verify carcass quality traits.

BQA: Studies on injection site lesions leading to product quality improvement.

Close research gaps and drive innovation

Unlock new possibility

Action can be limited by available solutions, tools, and technologies. Support for research and innovation can help close gaps and drive scaled adoption.

Opportunity areas for research include genetic innovation for adaptations like heat tolerance and enteric methane mitigation solutions fit for grazing environments, including assessing potential productivity gains from reducing enteric methane.

Additional research into productivity and environmental outcomes, financial ROIs, and producer barriers to transitioning to more resilient and resource-efficient feed crops could support beneficial transitions.

Food safety: Implemented mandatory training on safety and hygiene protocols.

CAB: Trained producers to meet defined brand specifications.

BQA: Trained value chain participants on BQA standards and practices to help producers remain competitive.

Welfare: Trained handlers using standardized animal behavior and handling principles.

Building capabilities

Developing high capacity

Train stakeholders across the value chain, from producers to processing plant managers and executives, on strategic, proactive decision making that optimizes economic returns through social and environmental resilience practices.

Cohorts who advance together can be a powerful approach, building group momentum and network knowledge.

Training can address point source challenges such as enhancing fitness-for-transport training to reduce quality losses, mortality, and morbidity associated with transport.

At the same time, training can build capacity for long-term business successes. For example, key stakeholders developing decision-making processes better equipped for today's more volatile operating conditions can support more effective business strategies that buffer risks.

Training can also be an investment in business and community succession and closing labor gaps. For example, engagement with young, beginner, and historically marginalized groups that builds region- and sector-specific knowledge and capacity.

IMPLEMENTATION & SCALING

Food safety: Established standard operating procedures for sanitation. **CAB**: Established guidelines for genetics and quality. **BQA**: Established best practices for low-stress handling and proper injection techniques. **Welfare**: Defined practice guidelines and scoring systems for animal handling and behavior.	**Set and leverage best practices**	**Operating guidelines** Recognize regional variability while defining best practice guidance across mitigation and adaptation actions that support value chain resilience by improving the health of ecosystems, communities and a habitable climate. Pair efficiency improvements with necessary absolute targets, such as water targets tied to replenishment rates in arid regions.	Best practices might include: Mitigation: Enhancing water use efficiency and reducing absolute water usage for feed and livestock production; coupling emissions intensity and absolute reductions. Mitigation and Adaptation: Eliminate sources of loss and waste in the value chain to avoid "wasted" resource inputs and emissions impacts, for example, liver abscess rates can be 2-3 times higher in beef-on-dairy cross-calves. Adaptation: Minimize impacts of extreme weather disruptions specific to key sourcing regions. For example, increasing proportion of drought-tolerant crops and varieties in forage and feed mixes to reduce losses and high costs during drought periods.
Food safety: Implemented phased rollout based on plant size over multiple years. **CAB**: Scaled from a regional pilot to a global brand over time. **BQA**: Began with voluntary guidelines that became increasingly required by major purchasers. **Welfare**: Piloted audit programs before scaling to full compliance requirements.	**Phased implementation**	**Phased adoption model** Action should reflect most critical company risks and be phased with consideration for regions that are most relevant, whether needed solutions are available, and which possible collaborators are primed to act. In implementation, begin with encouraging voluntary practice adoption including building capacity and infrastructure. Transition over time to market-gate requirements that support scale and success through value chain alignment.	Regional variation: Given geographic variation in agricultural systems and experienced climate disruptions, tailoring by region is critical. Start at regional levels and assess what is scalable. Solution readiness: Some solutions are implementable near-term, whereas others are still in the innovation pipeline. Consider how action now can both deliver impact and enable a greater menu of solutions down the line, teeing up future success. Support innovation while implementing known solutions.
CAB: Upfront investment in long-term transition to breed-specific infrastructure and marketing. **Welfare/BQA**: Capital allocation for facility retrofits to meet new handling standards funded through the industry-wide Beef Checkoff with some USDA grant matches.	**Unlock patient capital flows and access**	**Align capital to resilience timelines** Work with agricultural lenders and other funders to supply capital aligned with the timelines and needs of resilient beef production. Integrating public and private funding sources can be a critical catalyst for implementing and scaling resilience practice changes.	Existing sources of capital may not align with increasing weather risks and the financial needs of beef producers in adopting resilient systems. Blended finance approaches may be needed to stack multiple sources of capital and align with producer needs. Examples of where such finance may be key include supporting the beef industry through its 7–10-year market swings, meeting the longer biological timescales soil and aquifer replenishment require, and increasing adoption of adaptation technologies like water sensors, drone rangeland assessments, virtual fencing, solar energy, and more.

Food safety: Regulatory shift to HACCP mandatory implementation. **BQA/Welfare:** Industry-led standardization that eventually informed federal guidance and procurement requirements.	**Advocate for supportive policies**	**Focus on multi-win policies** Working early and often not only across the value chain, but with nearby communities is a powerful way to define and advocate for multi-win policies. Supportive policies can keep companies improving industry-wide resilience from bearing the brunt of costs for shared benefit.	Advocate for policies that increase support, such as higher cost-share payments for emissions reduction tools and practices, through USDA conservation programs like Environmental Quality Incentives Program and the Conservation Stewardship Program. Advocate for policies that support collective resilience and mitigation-oriented efforts through grants or other incentives that bolster investments made in high impact, cross-value chain partnerships.
TRACKING & TRANSPARENCY			
Food safety: Integrated critical control points (e.g., temperature, pH) into daily operations; established strict pathogen limits and safety thresholds. **CAB**: Integrated breed, marbling, and carcass specifications as primary performance metrics. **BQA**: Defined standards for animal handling and health; established certification programs; tracked and reduced quality indicators, including lesions and bruising. **Welfare**: Defined pass/fail criteria for animal welfare third-party audits; established animal welfare as a KPI with standardized performance metrics.	**KPI integration and progress tracking**	**Practical performance measurement** Use fit-for-purpose KPIs to track progress against both adaptation, such as water or labor availability, and mitigation, such as GHG emissions or nitrogen water pollution. Recognizing costs, complexity and time scale challenges, initial key metrics should be actionable and spatially consistent (standard framework), while capturing local variation. These metrics should provide information that is relevant on an operational scale.	The ROI on tracking resilience performance comes from embedding these resilience metrics into the financial / corporate strategy which depends on healthy water, soil, forage, feed and labor pools. Operationalizing these metrics in corporate structures might look like embedding staff trained in supply chain resilience into business operations; setting procurement standards; or assigning executive ownership of resilience targets.
Food Safety: Established science-based monitoring, recording, and verification as standard practice. **CAB**: Implemented fit for purpose traceability to verify compliance with brand standards. **BQA**: Required record-keeping to ensure compliance with health and safety standards. **Welfare**: Required documentation of audit results and corrective actions across facilities.	**Actionable measurement, verification, and reporting**	**Fit-for-purpose MRV systems** Implement systems that provide Scientifically robust, verifiable and actionable data on KPI progress. Being fit for purpose entails having adequate precision and accuracy to measure progress and balancing rigor with practicality to enable action, rather than slow it.	Leverage value chain collaborations and market gate incentives and requirements for shared MRV data infrastructure that supports the needs of different stakeholders. Leverage a split-gas accounting approach that separates greenhouse gases, including methane, to support improved prioritization of mitigation efforts. This may indirectly influence future adaptation needs by reducing near-term warming and other extreme weather by prioritizing methane reduction efforts.

Food Safety: USDA inspection seal served as the core certification for safety assurance.

CAB: Used certification labeling to build trust in product consistency.

BQA: Established certification programs to build market confidence.

Welfare: Leveraged third-party audits to validate compliance and build trust.

Trust building

Build trust

While formal resilience certifications may not be necessary at this point, trust is essential to market confidence and brand differentiation.

Communicate transparently on resilience and mitigation efforts, not only sharing progress toward KPIs and company-wide goals but noting key actions that are enabling progress (e.g., policy advocacy, innovation investments, participation in collective efforts) as well as core challenges and needs for continued progress. This shows commitment to action and sends demand signals for what is needed for continued sector-wide progress.

CALL TO ACTION

The U.S. beef industry has reached a pivotal moment. The pressures it now faces from environmental volatility, workforce instability, resource constraints, and tightening margins, are not temporary disruptions. They are structural shifts that require a new level of preventative action and pre-competitive coordination. The industry has successfully navigated moments that called for a paradigm shift before. These past shifts show that when a shared risk is clearly defined and tied to long-term viability, competitors can align incentives and policies, invest, and act to strengthen the entire system.

The sector has an opportunity today to couple resilience and mitigation efforts to strengthen and safeguard itself into the future by:

- Securing value by shifting from reaction to prevention models.
- Identifying the sometimes-invisible economic value that healthy social and environmental conditions enable and integrating them into decision-making.
- Progressing pre-competitive collaborations that align around both resilience best practices and systemic priorities.
- Establishing incentives and policies that secure the health of interconnected natural resources, producers, labor, and neighboring communities.
- Leveraging practical, fit-for-purpose data and verification systems that support decision-making, create transparency that builds trust, and enable action.

If designed intentionally, these shifts can evolve from tactical adaptations into the building blocks of a resilient system transformation.

The path forward is not about replacing something which works; it is about sustaining and building on what works so that the industry can be successful through the emerging 21st century operating reality. This will require different management in the face of volatility and constraint. The sector has an opportunity to act now to establish a beef system that safeguards the quality and efficiency that past shifts have created and supports agricultural and rural vitality in the face of change, collectively reaping the benefits from the co-creation of a more resilient system.

ACKNOWLEDGEMENTS

Several partners were critical to this research and process, including Kearney, Pontifex Consulting, Metropolitan Group, Colorado State University AgNext, Dragonfly Systems, LLC., and many Environmental Defense Fund staff. In addition, 37 stakeholders were engaged across interviews and the project's industry workshop, representing retail, food service, packers and processors, feedlot operators, ranchers, allied industry, trade associations, multistakeholder groups, government entities, and non-governmental organizations. Their insights and contributions were essential to creation of the system maps and analysis that underlie this work.

METHODOLOGY

This report is the result of a multidisciplinary and collaborative effort including sustainability and agriculture experts from Kearney; a dynamic systems mapping and modeling specialist from Pontifex Consulting; environmental and social justice specialists from Metropolitan Group; agricultural researchers from Colorado State University AgNext (CSU); a systems thinking expert from Dragonfly Systems, LLC; and Environmental Defense Fund.

The dynamic systems mapping methodology employed is designed to uncover the structural forces driving complexity in the U.S. beef system, with a focus from feed processing through animal processing, excluding retailers and consumers, with the exception of downstream demand signals from these stakeholders.

Kearney led and began this process by conducting an extensive review of the literature, that was complemented by an environmental justice-focused literature review by Metropolitan Group. To augment the literature reviews, both consultants conducted interviews with subject matter experts. The purpose of the interviews was to validate and refine interpretations of the literature and identify research gaps to improve the overall accuracy of the research.

Findings from the literature reviews and interviews were used by Pontifex Consulting in a dynamic systems mapping process with the goal of creating maps and narratives that could be used to visualize how the system works, with a focus on feed production through animal processing. The mapping process results in a more holistic, realistic viewpoint of the beef system as a complex inter-dependent system composed of feedback loops, delays, and nonlinearities rather than a simplistic, linear supply chain.

This systems approach supports uncovering root causes of system outcomes, identifying leverage points (specific places to intervene in a system) for change, and designing impactful intervention (specific actions that can be taken at a leverage point to create change) strategies toward a particular end, such as improving sustainability and social outcomes of the system. EDF defined that end by identifying core principles, values, and qualities around which the system could be structured to support desired outcomes.

The system maps not only visualize the current system but support scenario exploration of strategic interventions. Maps were utilized for this exploration in strategic workshops and discussions, informing recommendations elevated through this report. This analysis is intended to help EDF and stakeholders across the value chain explore the implications of and opportunities offered by strategies that can support desired change.

This report is a starting conversation and invitation to engage with EDF in systems thinking and leveraging the maps that underlie this report.

CITATIONS

[1] U.S. Meat Consumption Increases Despite Rising Prices. Farm Bureau, 2026.

[2] Smaller Cattle Herd Creates Market Volatility. Farm Bureau, 2024.

[3] Smaller Cattle Herd Creates Market Volatility. Farm Bureau, 2024.

[4] USDA Issues Final Emergency Livestock Relief Program Payments for 2023 and 2024 Drought, Flood and Wildfire Losses. U.S. Department of Agriculture, 2026.

[5] Drought Threatens the Herd Rebuild. The Cattle Range, 2026.

[6] Climate Change, Rangelands, and Sustainability of Ranching in the Western United States. New Mexico State University, 2020.

[7] America's Last Great Grasslands. Working Lands for Wildlife, n.d.

[8] Press Release: US is Losing 2.5 million Acres of Grasslands Annually. NBGI Technical Committee, 2024.

[9] Fewer Cows, Fewer Ranchers. Drovers, 2024.

[10] Farm Succession Planning Services for Your Family's Future. Farmers & Merchants Bank, n.d.

[11] Cattle & Beef - Sector at a Glance. U.S. Department of Agriculture, Economic Research Service, 2025.

[12] United States cattle inventory down slightly. U.S. Department of Agriculture, National Agricultural Statistics Service, 2026.

[13] Cattle & Beef - Sector at a Glance. U.S. Department of Agriculture, Economic Research Service, 2025.

[14] USDA - National Agricultural Statistics Service - Surveys - Cattle on Feed. USDA, 2025.

[15] Beef Industry Review and Consumer Insights: February 2025 Edition. Cattlemen's Beef Board & National Cattlemen's Beef Association, 2025.

[16] Smaller Cattle Herd Creates Market Volatility. Farm Bureau, 2024.

[17] Data Centers in the United States. Cleanview, 2026.

[18] Ogallala Aquifer Dropped More Than a Foot in Kansas in 2024. Farm Policy News, 2025.

[19] Groundwater levels continue to decline amid persistent drought conditions. IANR News. University of Nebraska–Lincoln, Institute of Agriculture and Natural Resources, 2026.

[20] Groundwater levels continue to decline amid persistent drought conditions. IANR News. University of Nebraska–Lincoln, Institute of Agriculture and Natural Resources, 2026.

[21] Drought Threatens the Herd Rebuild. The Cattle Range, 2026.

[22] Drought Threatens the Herd Rebuild. The Cattle Range, 2026.

[23] Climate Change, Rangelands, and Sustainability of Ranching in the Western United States. New Mexico State University, 2020.

[24] Smaller Cattle Herd Creates Market Volatility. Farm Bureau, 2024.

[25] Smaller Cattle Herd Creates Market Volatility. Farm Bureau, 2024.

[26] Groundwater levels continue to decline amid persistent drought conditions. IANR News. University of Nebraska–Lincoln, Institute of Agriculture and Natural Resources, 2026.

[27] Ogallala Aquifer Dropped More Than a Foot in Kansas in 2024. Farm Policy News, 2025.

[28] USDA Issues Final Emergency Livestock Relief Program Payments for 2023 and 2024 Drought, Flood and Wildfire Losses. U.S. Department of Agriculture, 2026.

[29] Drought Threatens the Herd Rebuild. The Cattle Range, 2026.

[30] Climate Change, Rangelands, and Sustainability of Ranching in the Western United States. New Mexico State University, 2020.

[31] America's Last Great Grasslands. Working Lands for Wildlife, n.d.

[32] Press Release: US is Losing 2.5 million Acres of Grasslands Annually. NBGI Technical Committee, 2024.

[33] Forest Destruction. Western Resource Advocates, n.d.

[34] Forest Destruction. Western Resource Advocates, n.d.

[35] Climate Change in the United States: Benefits of Global Action. EPA, 2015.

[36] Livestock Shade Structures -Costs and Benefits. NRCS Florida, 2007.

[37] EPA Releases Updated Climate Indicators Report Showing How Climate Change is Impacting People's Health and the Environment. EPA, 2024.

[38] Extreme Heat and Climate Change. Center for Climate and Energy Solutions, n.d.

[39] Extreme Heat and Climate Change. Center for Climate and Energy Solutions, n.d.

[40] Forest Destruction. Western Resource Advocates, n.d.

[41] Forest Destruction. Western Resource Advocates, n.d.

[42] Heat Waves in the Age of Climate Change: Longer, More Frequent and More Dangerous. New York Times, 2019.

[43] Meat quality and safety issues during high temperatures and cutting-edge technologies to mitigate the scenario. Journal of Animal Science Technology, 2024.

[44] USDA Issues Final Emergency Livestock Relief Program Payments for 2023 and 2024 Drought, Flood and Wildfire Losses. U.S. Department of Agriculture, 2026.

[45] Farm Succession Planning Services for Your Family's Future. Farmers & Merchants Bank, n.d.

[46] Farmers struggle as the insurance industry gets hammered by climate change challenges. Farm Commons, n.d.

[47] NEW REPORT: Extreme Weather is Fueling A Nationwide Home Insurance Crisis. Climate Power, 2025.

[48] Farm Labor. USDA, 2025.

[49] 2022 Census of Agriculture. USDA, 2024.

[50] Fewer Cows, Fewer Ranchers. Drovers, 2024.

[51] Farm Succession Planning Services for Your Family's Future. Farmers & Merchants Bank, n.d.

[52] Attributes of U.S. Farms by Number of Generations the Farm Has Been in a Family. Journal of the American Society of Farm Managers and Rural Appraisers, 2004.

[53] U.S. meatpacking industry relies on immigrant workers. But a labor shortage looms. Los Angeles Times, 2020.

[54] U.S. meatpacking industry relies on immigrant workers. But a labor shortage looms. Los Angeles Times, 2020.

[55] Meatpacking industry supports Trump but braces for deportation fallout. Axios, 2024.

[56] American Cancer Society Warns of Increase in U.S. Food Swamps. American Cancer Society, 2026.

[57] A Snapshot of Broadband Access in Rural Communities. 2M Research, 2022.

[58] 2025 rural health state of the state. Chartis, 2025.

[59] A Historical Perspective on the Holcomb Fire: Differences and Similarities to the COVID-19 Situation and Other Significant Market Events. University of Nebraska, Department of Agricultural Economics, Center for Agricultural Profitability, 2020.

[60] A Historical Perspective on the Holcomb Fire: Differences and Similarities to the COVID-19 Situation and Other Significant Market Events. University of Nebraska, Department of Agricultural Economics, Center for Agricultural Profitability, 2020.

[61] Farm Labor. U.S. Department of Agriculture, Economic Research Service, n.d.

[62] Meatpacking industry supports Trump but braces for deportation fallout. Axios, 2024.

[63] U.S. meatpacking industry relies on immigrant workers. But a labor shortage looms. Los Angeles Times, 2020.

[64] NIFA Impacts: Saving the Ogallala Aquifer, Supporting Farmers. USDA, 2020.

[65] NIFA Impacts: Saving the Ogallala Aquifer, Supporting Farmers. USDA, 2020.

[66] Carbon Neutral by 2030. Meat & Livestock Australia, n.d.