Agricultural Animal Biotechnology
Genome Editing

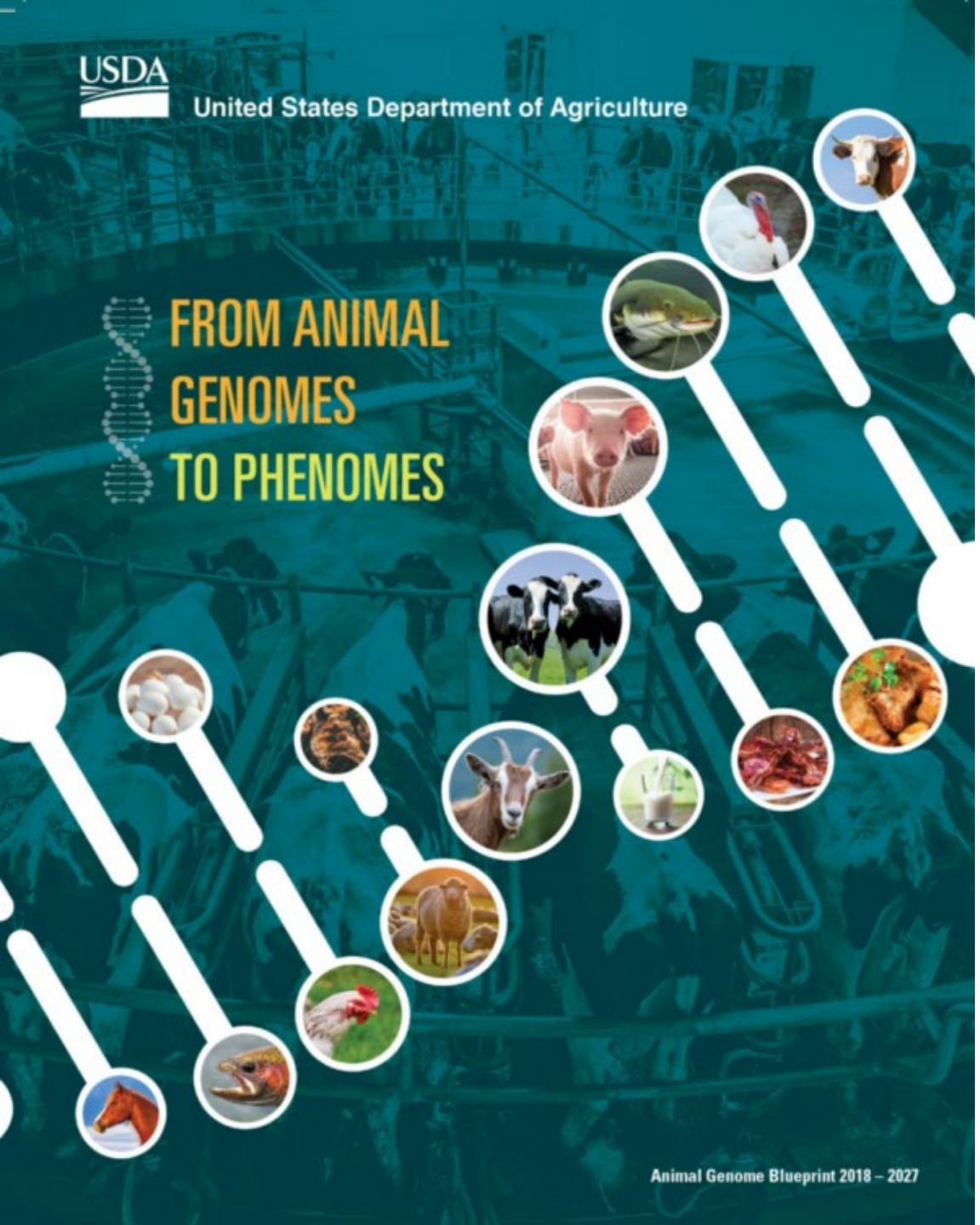
Steven J. Moeller, PhD

National Program Leader for Food Animal Production

Agricultural Research Service

Steven.Moeller@usda.gov

NASEM Workshop - February 2024



Genome to Phenome: Improving Animal Health, Production, and Well-Being – A New USDA Blueprint for Animal Genome Research 2018–2027

https://doi.org/10.3389/fgene.2019.00327

Goal 1: Providing Nutritious Food for a Growing Human Population

Goal 2: Improving Sustainability of Animal Agriculture

Goal 3: Increasing Animal Fitness and Improving Animal Welfare

Goal 4: Meeting Consumer Needs and Choices

U.S. DEPARTMENT OF AGRICULTURE

USDA SCIENCE AND RESEARCH STRATEGY, 2023 - 2026:

Cultivating Scientific Innovation

USDA'S FIVE SCIENCE PRIORITIES

Priority 1: Accelerating Innovative Technologies & Practices

- 1.1 Inclusive Innovation Culture
- 1.2 Technology-Enabled Decision Support Systems
- 1.3 Collaborative Intelligence Tools
- 1.4 Bioengineered Traits and Customizable Management Practices
- 1.5 Diversified Future Systems

Priority 2: Driving Climate-Smart Solutions

- 2.1 Climate Change Impacts
- 2.2 Climate Change Mitigation
- 2.3 Adaptation to a Changing Climate
- 2.4 Decision Support Tools
- 2.5 Bioeconomy

Priority 3: Bolstering Nutrition Security & Health

- 3.1 Inclusive Food Systems
- 3.2 Data Transparency
- 3.3 Predictive Analytics
- 3.4 Pathogen Virulence Factors
- 3.5 Food Systems Understanding & Impact

Priority 4: Cultivating Resilient Ecosystems

- 4.1 Genomics & Genome Editing
- 4.2 Microbiome Research
- 4.3 Sustainable Agro- & Aquatic-Ecosystems
- 4.4 Infectious Disease & Pests
- 4.5 Biodiversity

Priority 5: Translating Research into Action

- 5.1 Communication
- 5.2 Education & Workforce Development
- 5.3 Data Assets
- 5.4 Ag Science Policy

Bioengineered Traits and Customizable Management Practices

Objective 1.4

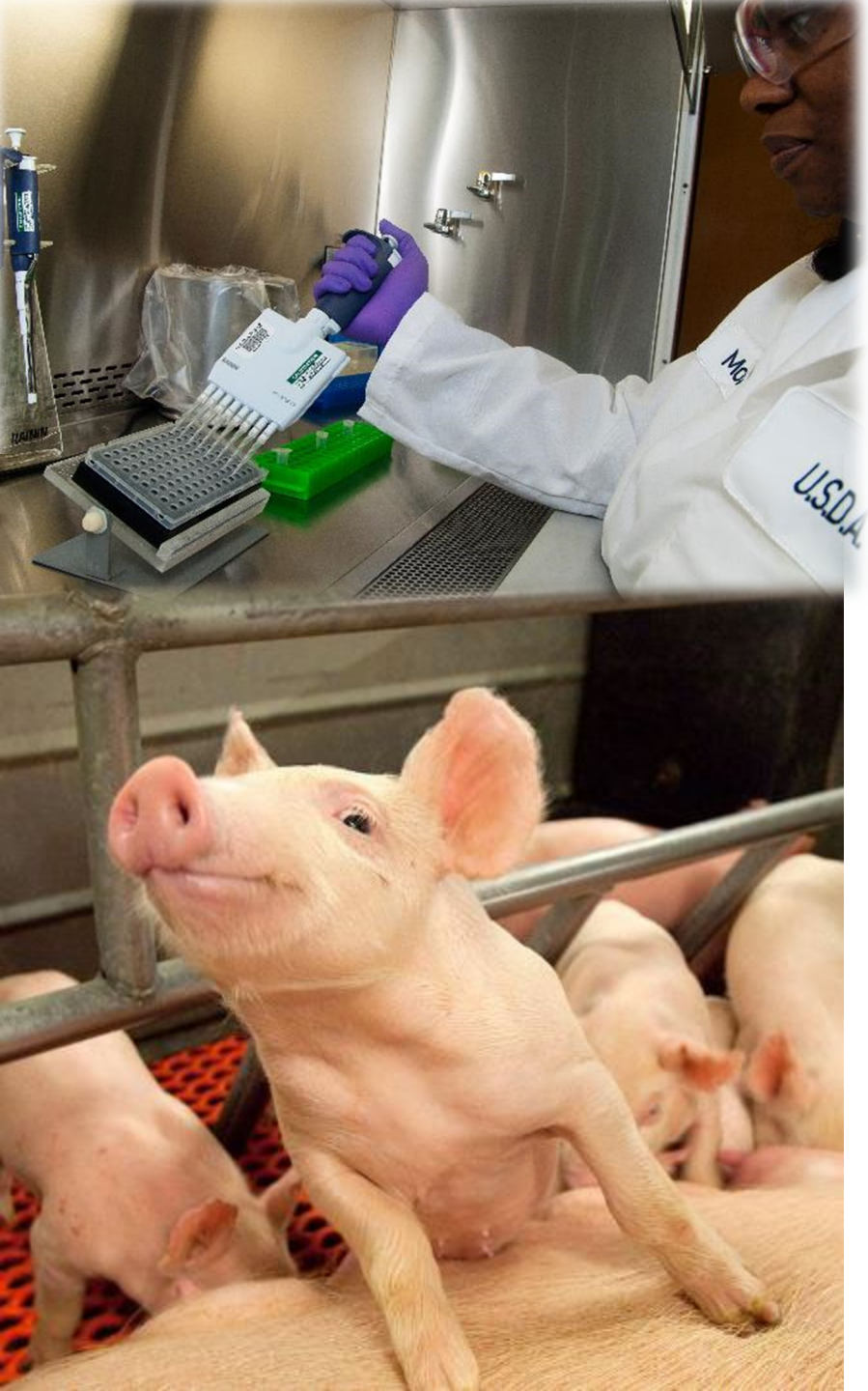
Improve sustainable production by developing novel selectable plant and animal traits, as well as advanced and customized agricultural and forestry management practices.

Genomics and Genome Editing

Objective 4.1

Determine the DNA sequences of plant and animal genomes and use this information to apply molecular biology techniques, such as genome editing and other advanced breeding methods to improve sustainability through research, including leveraging public-private partnerships and open science approaches.

Photo courtesy of Dr. Tim Smith



USDA SCIENCE & RESEARCH STRATEGY

2023-2026

Priority 5:

Translating Research Into Action

Getting USDA Research Solutions to Farmers

Animal Agriculture Research – USDA as Stewards of Federal Funds

USDA ARS - Congressionally Appropriated Research Funding

- Stakeholder engaged research priority setting
- Permanency in year-to-year funding
- Agricultural Research in support of producers & communities of all sizes
  - **Mission: ARS delivers scientific solutions to national and global agricultural challenges**

USDA NIFA – Congressionally Appropriated Funding

- Federal Funding to Morrill Act Institutions (1862, 1890, Tribal)
- Federal Funding through Hatch and Smith-Lever Acts
- Competitive Grants Funding in Priority Areas
  - **Mission: Provide leadership and funding for programs that advance agricultural-related sciences**

USDA

NIFA

Photo courtesy of Dr. Joan Burke

‘Genomics’ A Foundation of ARS Animal Research

USDA ARS Animal Production and Protection National Programs

- 101 – Food Animal Production
  - 2 projects involve genome editing
  - 13 projects involve animal genomics
- 103 – Animal Health
  - 1 project directly involves genome editing
  - Multiple projects evaluate genomics of disease-causing organisms and genetic tools for disease control strategies
- 104 – Veterinary, Medical, and Urban Entomology
  - Multiple genetics and genomics projects
- 106 – Aquaculture
  - 1 project involves genome editing
  - Multiple projects involve genomics for selection and improvement

USDA National Institute of Food and Agriculture (NIFA)

Funding

- Biotechnology Risk Assessment Research Grants (BRAG) (plants, animals, microbes) $6 million per year
- Animal Genome Editing: $28+ million in previous 5 years

Food Species:

- Cattle: Beef, Dairy
- Swine
- Poultry: Chickens, Quail
- Fish: Trout, Catfish, Tilapia

Animal Pests:

- Screw worms
- Ticks

Research on Traits:

- Disease Resistance & Resilience: PRRSv, BVD, TB, Influenza (avian, swine)
- Environment & Climate Change: Heat Tolerance, lower GHG emissions, lower waste outputs
- Animal Welfare & Improved Farm Practices: gender skewing, hornless, castration-free, no tail docking, in-ovo sexing
- Production & Diversity Traits: meat tenderness, reproduction, growth rate, rare breed preservation
- Treatments & diagnostics: Vaccines, pest controls

USDA Animal Biotech and Genomics Research

ARS Center – GnEd Research

ARS Center – Genomics Research Supporting GnEd

NIFA support – GnEd Research

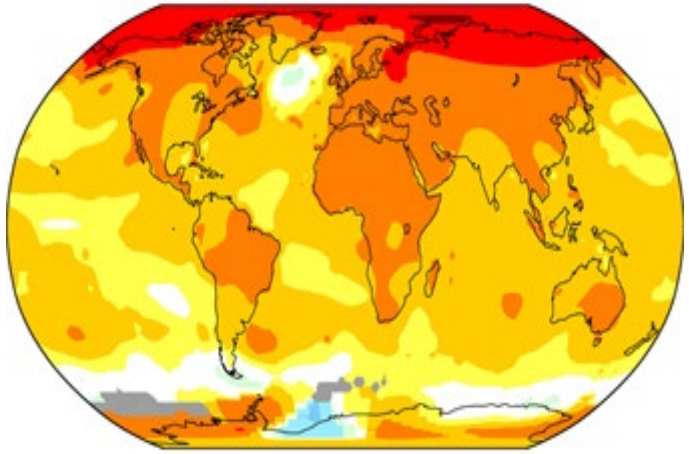
Future of (Animal) Agriculture

Unprecedented agricultural challenges globally

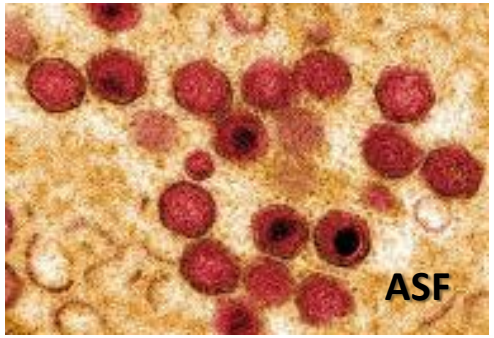
- Climate change
- Existing & Emerging disease and pest threats
- Increased production efficiency
- Reduced/limited land & water resources

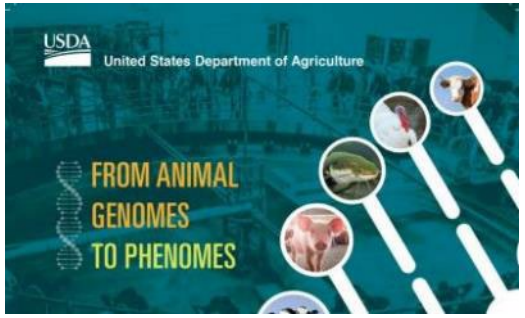
A need to transform agriculture

- Increase resilience
- Decrease environmental impact



2011-2020 average vs 1951-1980 baseline



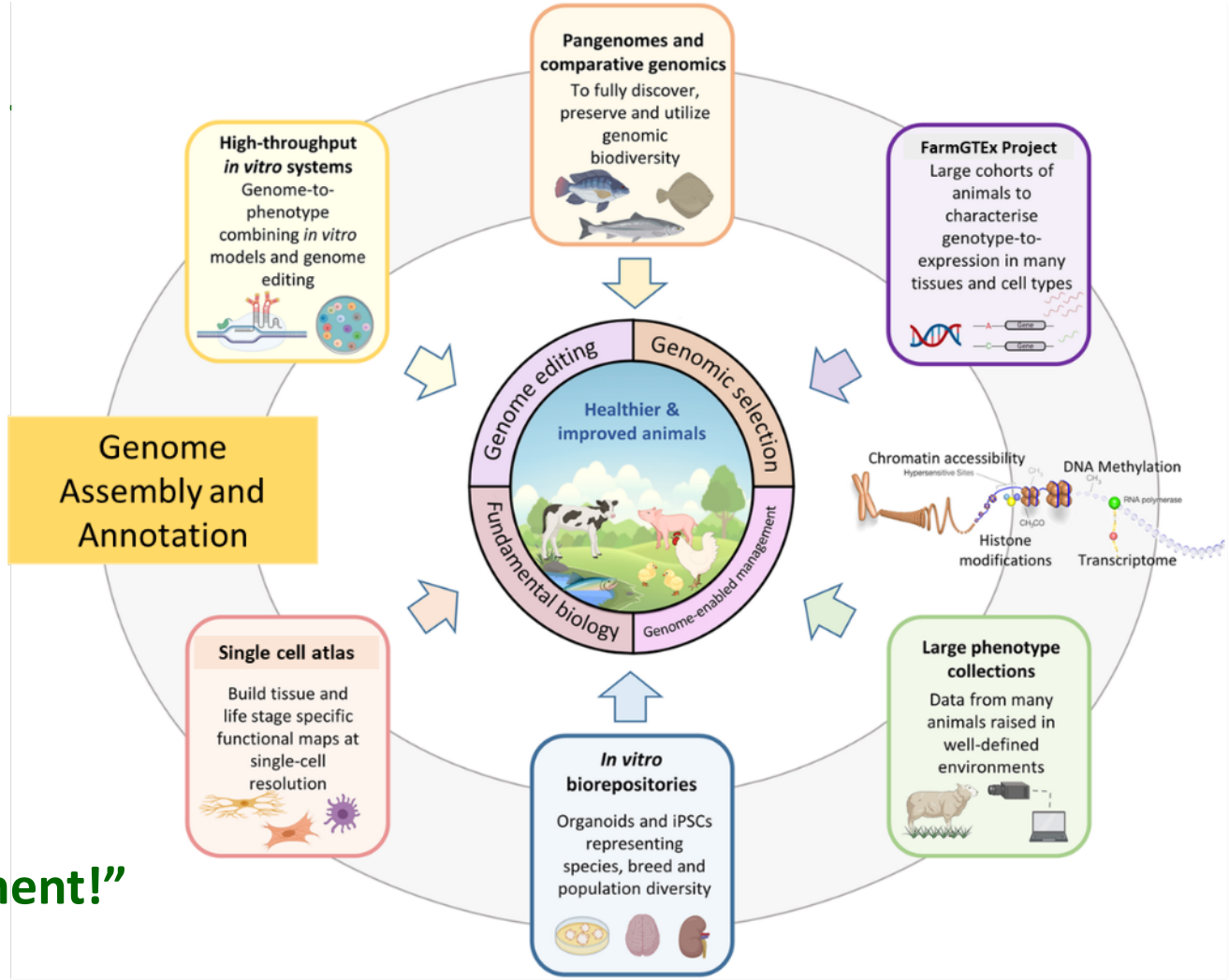


Biotechnology Supporting SOLUTIONS!

Global challenges require Global responses and Cooperation

Genome Toolbox Expansion

Unprecedented Technological Advances and Scientific Discovery Expanding Genomic Capacity to Improve Livestock



Modified from Genome Biology 21: 285

"Next-Generation Genetic Improvement!"

Perspectives on Biotech in Animal Agriculture

Genome Edits

- Mutations are the source of evolutionary species differentiation and within species variation
- Intentional Change(s) in a Genome, as proposed within a species, investigate natural mutation potential and apply new science to help solve problems
  - Science driven edit targets
  - Outcomes are not expected to be outside of impacts of natural mutation
  - Necessary to conduct science-based evaluation of outcomes (intended and any unintended outcomes)
- Edits may enhance accuracy and improve the rate of genetic improvement
  - Demonstrated positive impacts in plants can be mimicked in animals
  - Rapid and more efficient introduction of valued traits into breeding populations
  - More choices for the producer
- Downstream Effects
  - Reduced Antimicrobial Resistance
  - Reliably safer food products

Animal Genome Editing Research Challenges

TIMELINES LONG

***in-vitro* to *in-vivo* often years**

+

Additional years to population introgression

PATHS CURVY

Success Rates often Low

Trial & Error = Research

INPUTS COSTLY

Technology, Infrastructure, Personnel

(In)Consistency of funding

Photo courtesy of Dr. Aspen Workman

Animal Genome Editing Research Application Challenges

Accessibility

Public access for public funded efforts

Life-cycle studies are essential, but challenging to complete due to many factors

Partnerships

Who, what, where, when, & how?

Public – Private Agreements

ROI

Intellectual Property Agreements

Editing Technology Licensing

Food Systems Focused Efforts

Competing Interests

Prioritization

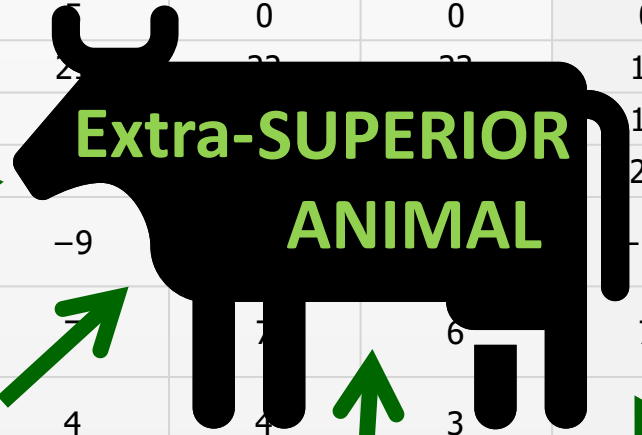
Stakeholder input and support are essential – We need your input on how to implement and move forward

USDA ARS

Photo courtesy of Dr. Clay Lents

IMPACT: Add Even Greater Value to Genetically Superior Animals

Trait	USDA dairy cattle genetic-economic selection index (year introduced)										
	PD$ (1971)	MFP$ (1976)	CY$ (1984)	NM$ (1994)	NM$ (2000)	NM$ (2003)	NM$ (2006)	NM$ (2010)	NM$ (2014)	NM$ (2017)	h^2
Milk	52	27	−2	6	[illegible]	0	0	0	**−1**	**−1**	**0.20**
Fat	48	46	45	25	[illegible]	[illegible]	[illegible]	19	**22**	**24**	**0.20**
Protein		27	53	43	[illegible]	[illegible]	[illegible]	16	**20**	**18**	**0.20**
Productive life				20	[illegible]	[illegible]	[illegible]	22	**1[illegible]**	[illegible]	**0.08**
Somatic cell score				−6	−9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	**0.12**
Udder composite					[illegible]	7	6	7	**8**	**7**	**0.25**
Feet/legs composite					4	4	3		**3**	**3**	**0.17**
Body size composite					−4	−3	−4	−6	**−5**	**−6**	**0.42**
Daughter pregnancy rate							9			**7**	**0.04**
Calving ability							6			**5**	**0.048**
Cow conception rate									**2**	**2**	**0.016**
Heifer conception rate									**1**	**1**	**0.01**
Cow liveability										**7**	**0.0062**



Reduction in GHG

Desired Phenotype

Genotype fits Environment (GxE)

Multi-Disease Resistance

Thermo-Resilience

Add Multiple Desirable traits to already Superior Animals

Thank you!

Steven.Moeller@usda.gov

Thank You to Dr. Diane Wray-Cahen (USDA, OCS) for Material and Content Support