Are “alternative” meats an end-product improvement?

Alison Van Eenennaam

Cooperative Extension Specialist

Animal Biotechnology and Genomics

Department of Animal Science

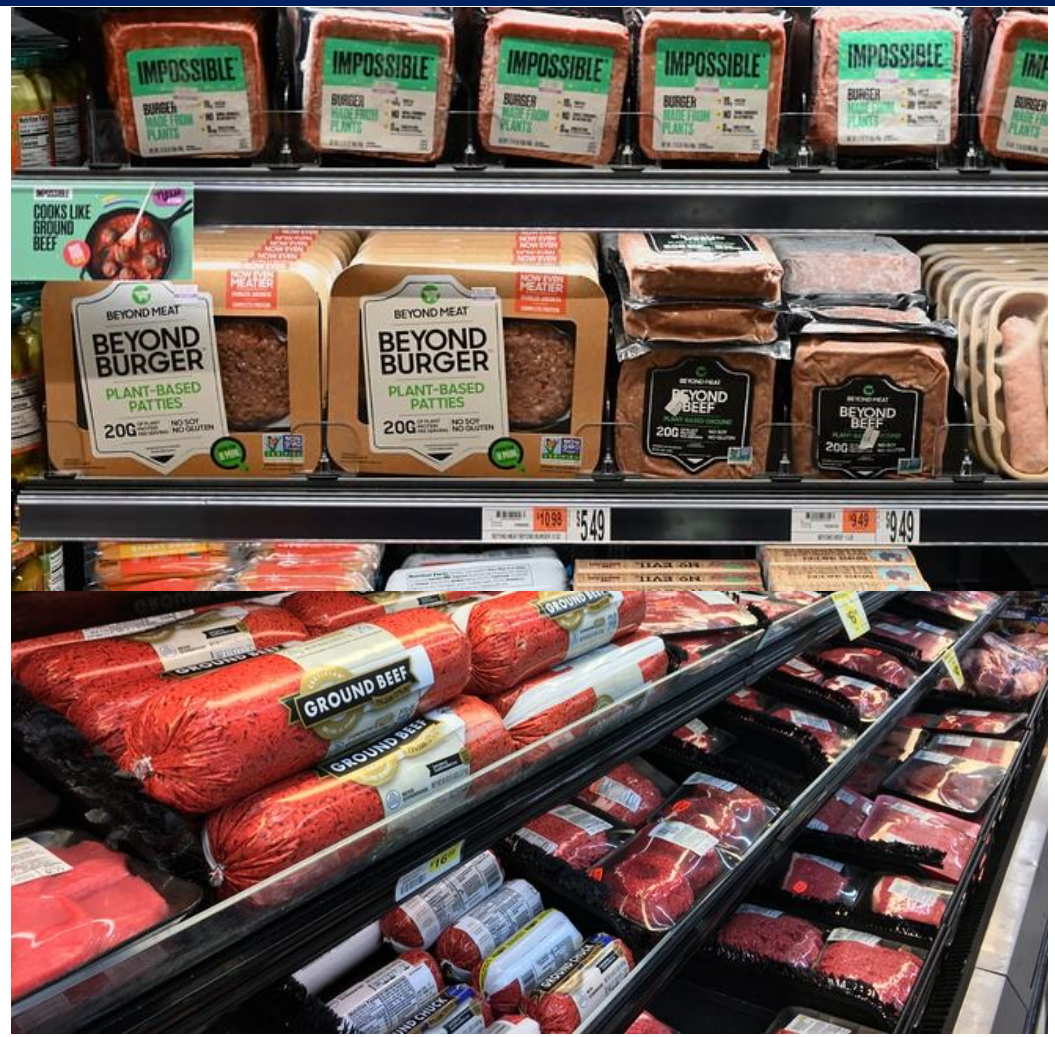
University of California, Davis, USA

Email: alvaneenennaam@ucdavis.edu

Twitter: **@BioBeef**

BLOG:https://biobeef.faculty.ucdavis.edu/

http://animalscience.ucdavis.edu/animalbiotech



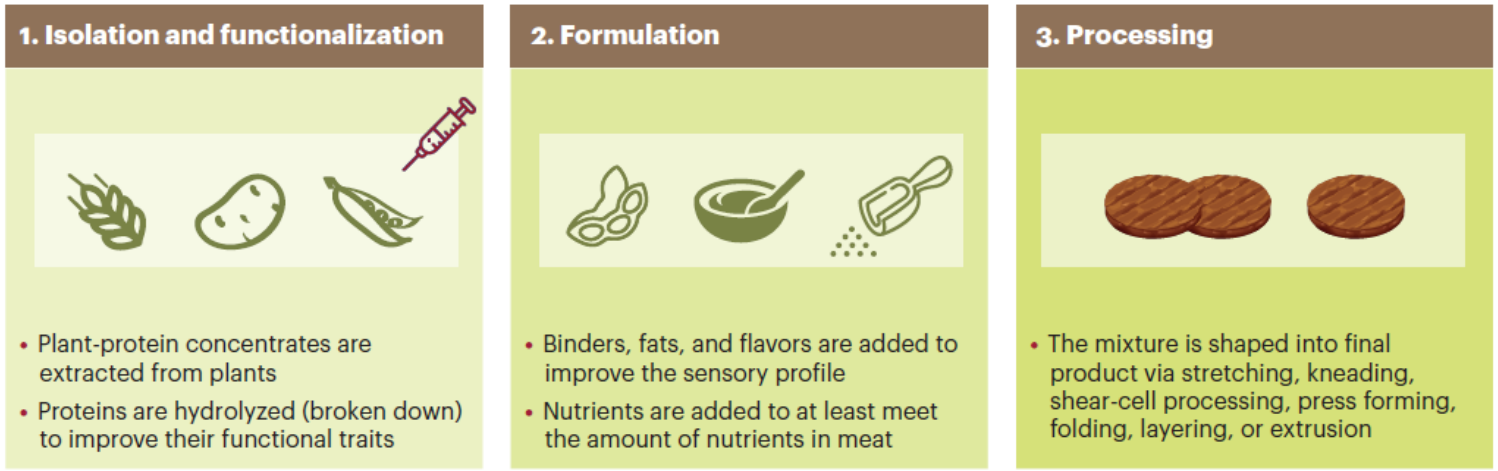
UCDAVIS
ANIMAL SCIENCE

What is an “end-product” improvement?

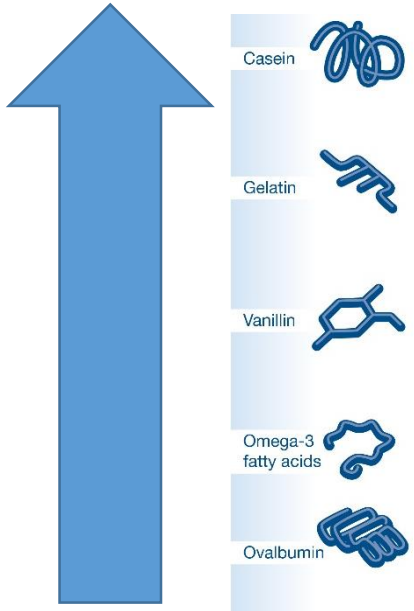
- Better product attributes
- Better taste
- Better price
- Better nutritional attributes
- Better sustainability metrics
    - GHG
    - Land Use
    - Water
    - Industrial Energy Use

Alternative meats: two distinct products

Vegan meat substitutes



e.g. Impossible Burger - soy
Beyond Burger - pea
JUST – yellow pea, mung bean



Cellular Agriculture Additives:
There are often also proteins and other compounds synthesized by recombinant yeast, fungi or bacteria grown in culture; these products include milk and egg proteins, gelatin, fatty acids, & vitamins like B_{12} that are harvested and added to the final product
e.g. soy leghemoglobin in Impossible Burger

Sources: Good Food Institute, Impossible Foods; A.T. Kearney analysis

EMBO Rep, Volume: 20, Issue: 1, First published: 14 December 2018, DOI: (10.15252/embr.201847395)

https://www.atkearney.com/retail/article/?/a/how-will-cultured-meat-and-meat-alternatives-disrupt-the-agricultural-and-food-industry

UC DAVIS ANIMAL SCIENCE

Alternative meats: two distinct product types

Vegan meat substitutes

1. Isolation and functionalization

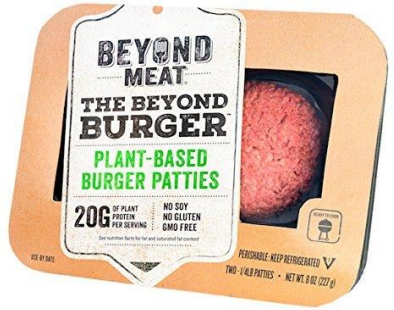
- Plant-protein concentrates are extracted from plants
- Proteins are hydrolyzed (broken down) to improve their functional traits

2. Formulation

- Binders, fats, and flavors are added to improve the sensory profile
- Nutrients are added to at least meet the amount of nutrients in meat

3. Processing

- The mixture is shaped into final product via stretching, kneading, shear-cell processing, press forming, folding, layering, or extrusion



e.g. Impossible Burger - soy
Beyond Burger - pea
JUST – mung bean

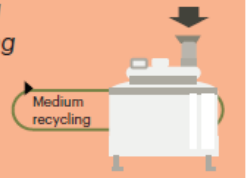
"in-vitro" or "cultured" or "cell-based" meat

1. Cell isolation

- An adult stem cell—called a satellite cell—is extracted from an animal
- One cell is sufficient for the process and the animal can live on

2. Cell proliferation

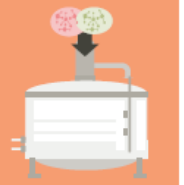
The cells are added to a bioreactor along with cell culture media, which causes the cells to proliferate.



- The result is exponential growth of the satellite cell
- Cells are fed by a medium containing amino acids, salts, sugars, and signaling molecules

3. Tissue perfusion

A change in culture conditions pushes the cell to differentiate into muscle, fat, and connective tissue.



- Cells are structured via 3D scaffolding materials to muscle fibers
- Muscle fibers are combined with fat to meat

e.g. Memphis Meats
New Age Meats

Sources: Good Food Institute, Impossible Foods; A.T. Kearney analysis

https://www.atkearney.com/retail/article/?/a/how-will-cultured-meat-and-meat-alternatives-disrupt-the-agricultural-and-food-industry

UCDAVIS ANIMAL SCIENCE

According to a 2019 *ATKearney* report:

"Novel vegan meat replacements and cultured meat have the potential to disrupt the meat industry"

Authors

Dr. Carsten Gerhardt
Partner

Gerrit Suhlmann
Consultant

Fabio Ziemßen
Director Food Innovation, NX-Food (Metro AG)

Dave Donnan
Partner

Dr. Mirko Warschun
Partner

Dr. Hans-Jochen Kühnle
Consultant

By 2040
"only 40% of global meat consumption will still come from conventional meat sources"

https://www.atkearney.com/retail/article/?/a/how-will-cultured-meat-and-meat-alternatives-disrupt-the-agricultural-and-food-industry

UCDAVIS ANIMAL SCIENCE

The meat replacement industry is attractive for venture $

Selected cultured meat companies

Appleton Meats	*Biofood*	*Memphis Meats*
biftec.co	*New Age Meats*	*Integriculture*
FM	*Meatable*	*mosa meat*
Mission Barns	*Balletic Foods*	*Hs Higher Steaks*
avant	*Aleph Farms*	*JUST*
Kiran	*SuperMeat*	

$50 million
in global funding
up to 2018

Established novel vegan meat replacement brands

Ojah	*Sunfed*
Field Roast	*Like Meat*
Beyond Meat	*JUST*
IMPOSSIBLE	*right {treat}*
Moving Mountains	*No Evil*

$900 million
in global funding
up to 2018

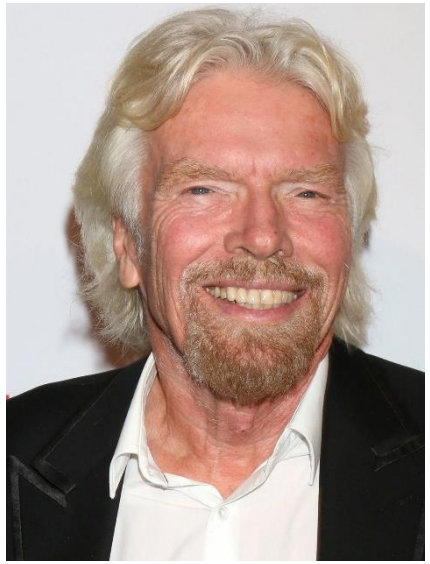
Source: A.T. Kearney analysis

https://www.atkearney.com/retail/article/?/a/how-will-cultured-meat-and-meat-alternatives-disrupt-the-agricultural-and-food-industry

UCDAVIS
ANIMAL SCIENCE

Who's Investing?

Bill Gates ($105.4 billion)



Richard Branson ($3.8 billion)

Li Ka-shing ($29.4 billion)

Leo DiCaprio ($235 million)

Sergey Brin ($53.8 billion)

Henry Soesanto (? net worth)

Tyson Foods, Cargill, Horizons Ventures, New Harvest

Cargill®

Horizons Ventures 維港投資

NEW HARVEST

UCDAVIS ANIMAL SCIENCE

According to The Good Food Institute (who are "laser focused on using markets and food technology to transform our food system away from factory farmed animal products and toward clean meat and plant-based alternatives")

Plant-based companies raised $741 million in investment capital in Q1 2020, nearly matching the $747 million raised in 2019

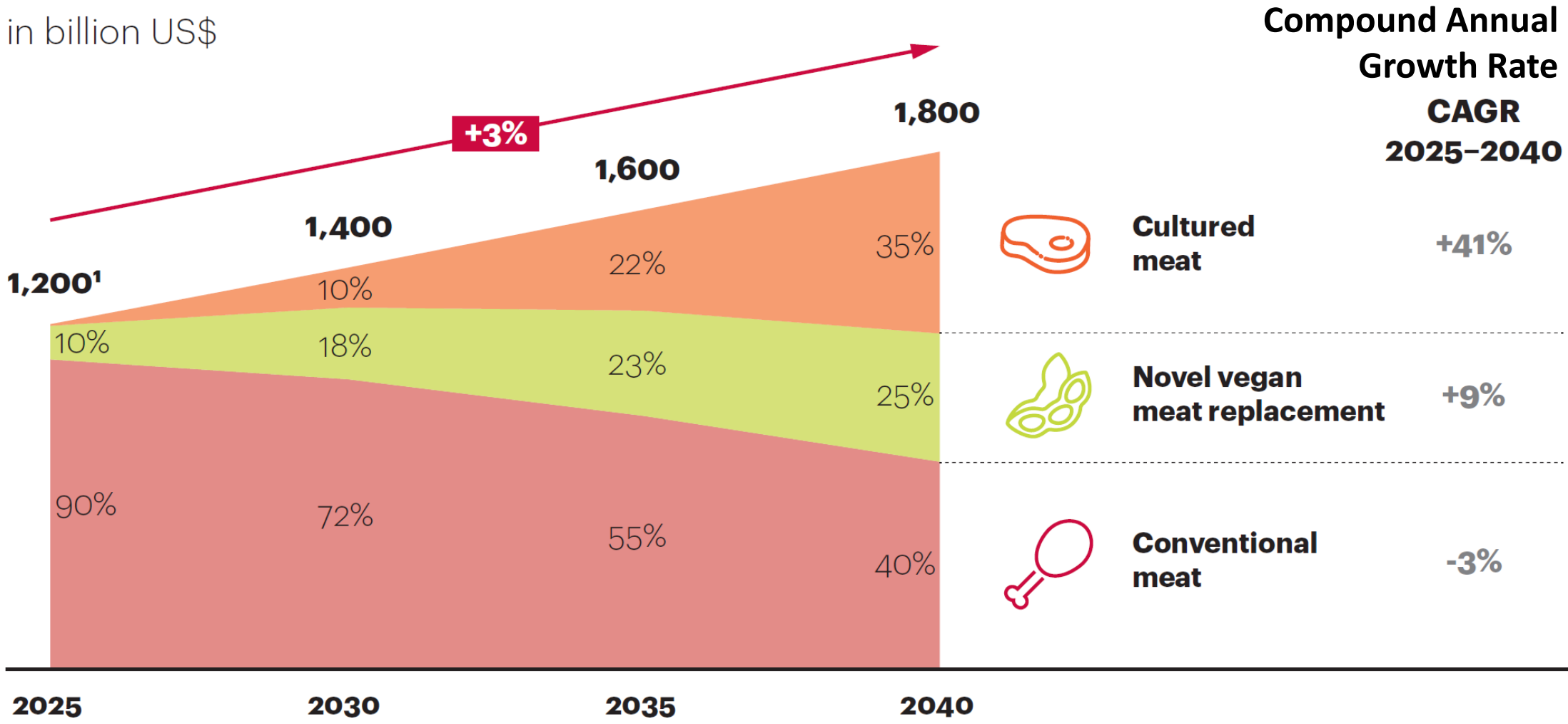
Investments in plant-based companies in 2020 (non exhaustive)	
Company	Amount raised
rebellyous foods	$6 million
IMPOSSIBLE™	$500 million
plantible	$4.6 million
the LIVEKINDLY co.	$200 million

Source: The Good Food Institute, "New GFI State of the Industry Reports Show Alternative Proteins are Poised to Flourish Post-Covid-19" (May 2020)

UCDAVIS ANIMAL SCIENCE

According to the 2019 *ATKearney* report

"Novel vegan meat replacements and cultured meat have the potential to disrupt the meat industry"



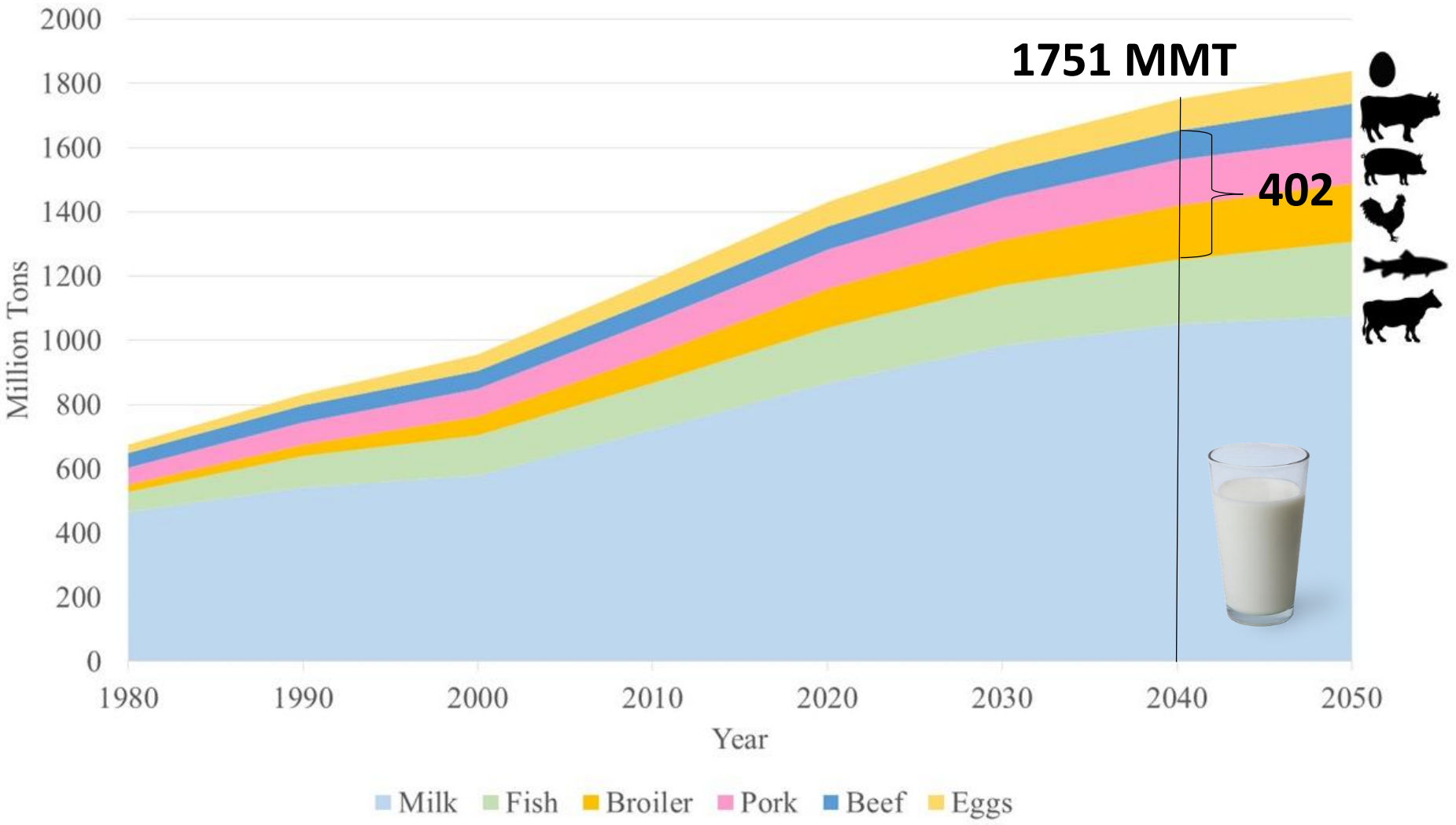
¹ Numbers are rounded to hundred billions.

Sources: United Nations, World Bank, Expert interviews; A.T. Kearney analysis

https://www.atkearney.com/retail/article/?/a/how-will-cultured-meat-and-meat-alternatives-disrupt-the-agricultural-and-food-industry

Egg, beef, pork, chicken, fish and milk production since 1980 and projected to 2050

(FAO 2018; Alexandratos and Bruinsma, 2012).



UCDAVIS
ANIMAL SCIENCE

If by 2040 cultured meat will be 35% and vegan meat replacements will be 25% of global meat production then

So doing the simple math, and assuming that only the **402 MMT of land-based meat production** is replaced with "quarter pounders" of the alternative source that would be [(.25 x 402 MMT) X (1,000,000,000/0.1133981)] =

886,258,235,367 plant-based quarter pounders

(Eight hundred and eighty-six billion, two hundred and fifty-eight million, two hundred and thirty-five thousand, three hundred and sixty-seven)

and for the cultured meat the calculation is (.35 x 402 MMT)X(1,000,000,000/0.1133981)] =

1,240,761,529,514 cultured meat quarter pounders

(One trillion, two hundred forty billion, seven hundred and sixty-one million, five hundred and twenty-nine thousand, five hundred and fourteen)

by 2040 (~ 20 years)

Are there data available to make an evidence-based assessment of end-product improvement?

Attribute	Meat	Vegan Meat Replacements	Cultured Meat
US production (lbs/yr)	105 billion (99.8%)	200 million (0.2%)	**0**
Nutrition	Yes	Yes	**?**
Price	Yes	Yes	**?**
Taste	Personal preference	Personal preference	**?**
Sustainability Metrics	Yes	Yes	**?**

UCDAVIS ANIMAL SCIENCE

Living cells in the bioreactor must be provided with nutrients in a suitable growth medium containing food-grade components that must be effective and efficient in supporting and promoting muscle cell growth

A typical growth medium contains

- **an energy source such as glucose**
- **synthetic amino acids**
- **fetal bovine serum**
- **horse serum**
- **antibiotics**

If cultured meat is to match or exceed the nutritional value of conventional meat products, nutrients found in meat not synthesized by muscle cells must be supplied as supplements in the culture medium.

- **Essential amino acids**
- **Vitamin B_{12}**
- **Iron**
- **Micronutrients**

Fermentation/Culture

UCDAVIS ANIMAL SCIENCE

Jerusalem Post Hi tech news 10/10/2019

ISRAELI START-UP TO BUILD WORLD'S FIRST LAB-GROWN MEAT PRODUCTION FACILITY

Future Meat Technologies EVP R&D Dr. Moria Shimoni, founder and chief scientist Prof. Yaakov Nahmias, and CEO Rom Kshuk. (photo credit: DUDI MOSKOVITZ)

Jerusalem biotechnology company **Future Meat Technologies** has announced it will establish the world's "**first cultured meat pilot production facility**," producing GMO-free meat cultivated directly from animal cells on a commercial scale.

The company plans to establish the facility south of Tel Aviv and begin operations next year. The expansion of research and development efforts come after the start-up secured **$14 million** in a Series A funding round.

https://www.jpost.com//Jpost-Tech/Israeli-start-up-to-build-worlds-first-lab-grown-meat-production-facility-604184

UCDAVIS ANIMAL SCIENCE

Jerusalem Post Hi tech news 10/10/2019

ISRAELI START-UP TO BUILD WORLD'S FIRST LAB-GROWN MEAT PRODUCTION FACILITY

This picture from the article had no caption…..is it lab-grown meat or chicken?

The company says its laboratory-based manufacturing model results in 99% less land use and 80% fewer greenhouse emissions that traditionally produced meat. The company plans to introduce hybrid products into the market, combining plant proteins for texture with cultured fats to create the aroma and flavor of meat.

While existing costs are $150 per pound of chicken and $200 per pound of beef, it aims to market its hybrid products at a "competitive cost level" from its pilot production facility by 2021.

https://www.jpost.com//Jpost-Tech/Israeli-start-up-to-build-worlds-first-lab-grown-meat-production-facility-604184

UCDAVIS ANIMAL SCIENCE

Jerusalem Post Hi tech news 10/10/2019

ISRAELI START-UP TO BUILD WORLD'S FIRST LAB-GROWN MEAT PRODUCTION FACILITY

The company's manufacturing process, during which fibroblast cells double in mass every 24 hours, enables the production of cell-grown chicken, lamb and beef within only two weeks.

The funding was led by **Chicago**-based venture capital firm S2G Ventures, a leading backer of successful meat substitute developer Beyond Meat, and **Swiss** venture capital firm Emerald Technology Ventures. They were joined by investors Henry Soesanto, the CEO of **Philippine**-based food manufacturer Monde Nissin; **UK-based** venture capital firm Manta Ray Ventures; and **Chinese** food and agriculture technology venture capitalist firm Bits x Bites.

"**With this investment, we're thrilled to bring cultured meat from the lab to the factory floor and begin working with our industrial partners to bring our product to market**,"
said Future Meat Technologies CEO Rom Kshuk.

https://www.jpost.com//Jpost-Tech/Israeli-start-up-to-build-worlds-first-lab-grown-meat-production-facility-604184

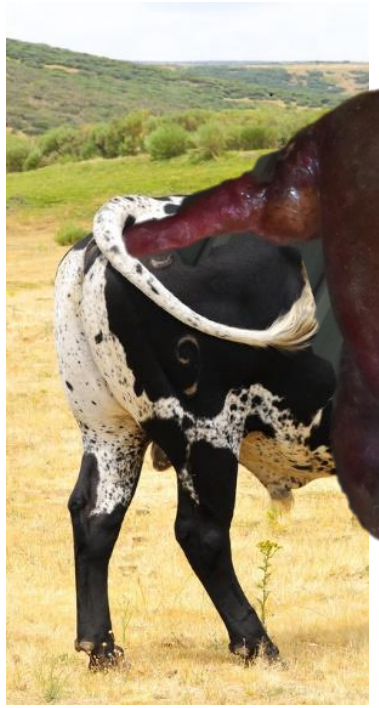
UCDAVIS ANIMAL SCIENCE

In 2013, Dutch Professor Mark Post unveiled the world's first slaughter-free hamburger to a packed press conference in London. It was the result of years of research at Maastricht University, and cost $335,000 to make. The effort was funded by Sergey Brin, the co-founder of Google.

© David Parry/PA Wire

To date, there is no process for proliferating not just muscle cells but also fat cells, which are particularly relevant for taste. It is also not yet possible to produce larger pieces of meat such as steaks.

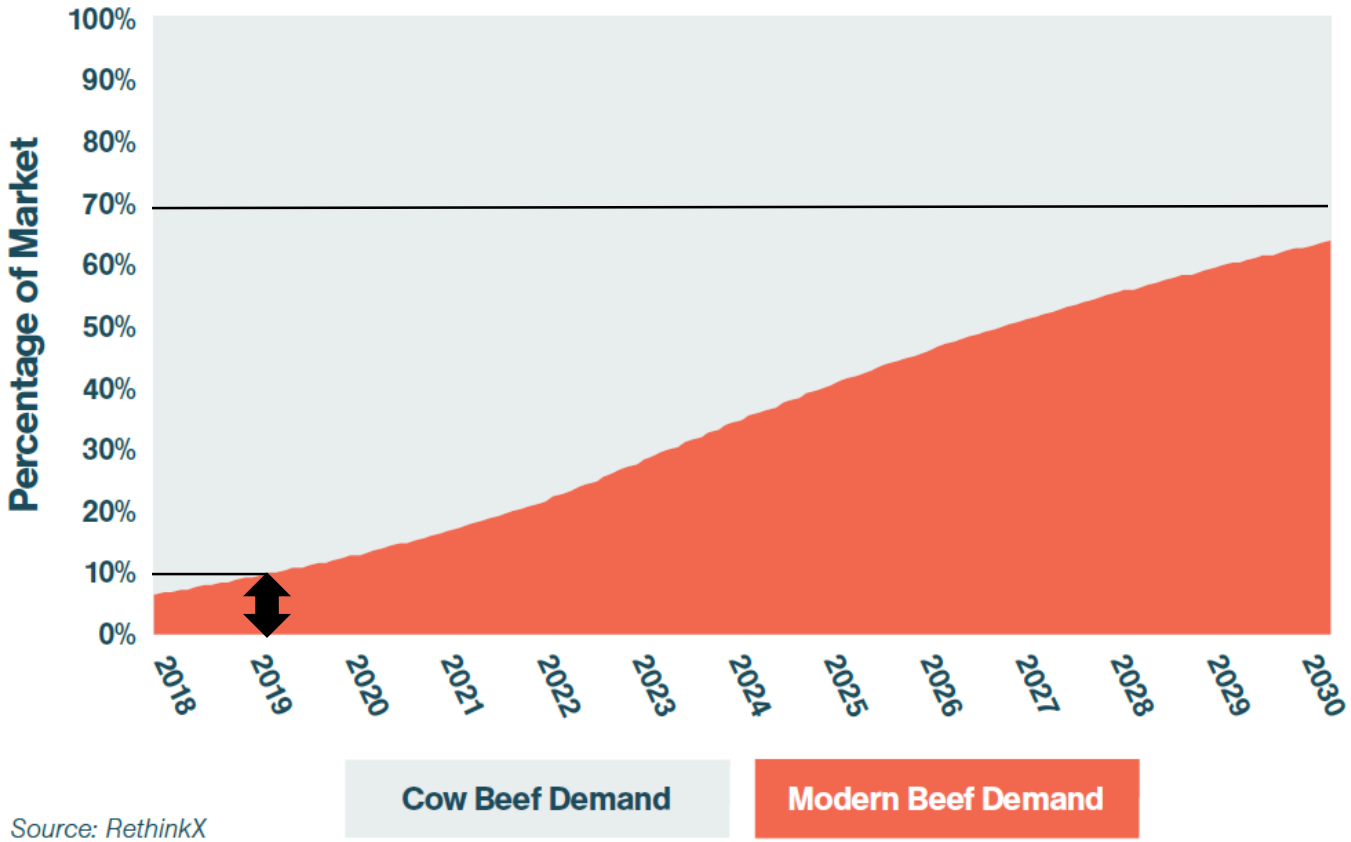
Self-propelling, self-cleaning, solar-powered, cellulose-driven bioreactor



According to a 2019 RethinkX report:

"*Fermentation farms will be the new food farms*". There will be job opportunities engineering, designing, building, & operating them.

Figure 12. U.S. Market Share of Cow vs. Modern Beef Products



*By 2030 "70% of all beef consumed will come from **modern production methods**" (i.e. not cows)*

Source: RethinkX

RethinkX+Food+and+Agriculture+Report.pdf (September 2019) https://www.rethinkx.com/food-and-agriculture

UCDAVIS
ANIMAL SCIENCE

Is 10% of meat production coming from alternative meat sources? NO

"In the United States, we produce more than 105 billion pounds of animal meat each year. Best estimates of U.S. plant-based meat production hovers just around 200 million lbs per year. That's a fifth of one percent (0.2%) of the total U.S. meat production by volume*."

*Because plant-based is 4-5 fold more expensive that meat, it is ~ 1% of sales but only 0.2% of weight sold

https://www.linkedin.com/pulse/why-plant-based-meat-hasnt-stopped-climate-change-yet-lagally/

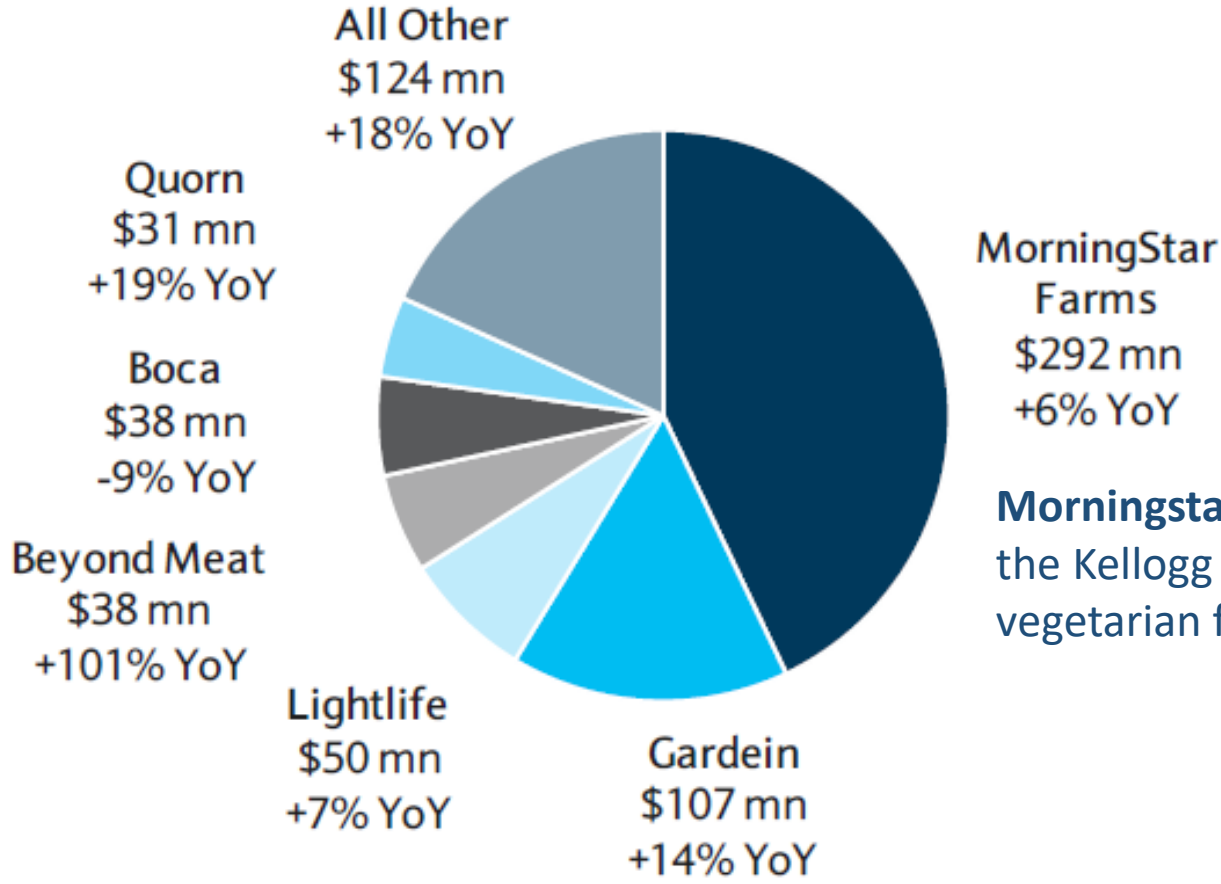
Van Eenennaam 6/11/2020


IMPOSSIBLE
BURGER
MADE FROM PLANTS
IMPOSSIBLE
BURGER
MADE FROM PLANTS
IMPOSSIBLE
BURGER
MADE FROM PLANTS
IMPOSSIBLE
BURGER
MADE FROM PLANTS
IMPOSSIBLE
BURGER
COOKS LIKE GROUND BEEF
BEYOND MEAT
BEYOND BURGER
PLANT-BASED PATTIES
20G
NO SOY
NO GLUTEN
BEYOND MEAT
BEYOND BURGER
PLANT-BASED PATTIES
20G
NO SOY
NO GLUTEN
BEYOND BEEF
20G
BEYOND BEEF
20G
$10.98
$5.49
$9.49
$9.49

UCDAVIS
ANIMAL SCIENCE

There are many brands of meat alternatives

Frozen/Refrigerated Meat Alternatives (Dollar Sales, % Chg vs YA)

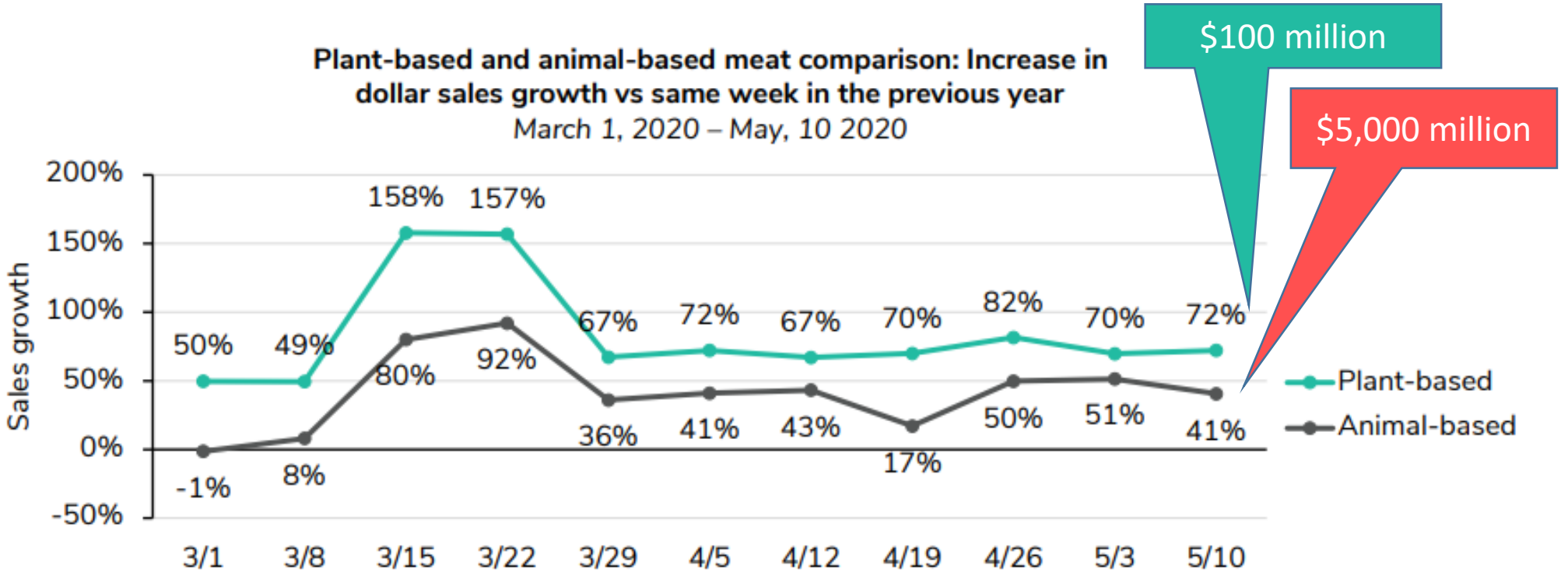


Morningstar Farms is a division of the Kellogg Company that produces vegetarian food.

Source: Barclays Research, Company Reports, IRI POS MULO+C L52W ending 02/24/19, IRI Growth Consulting Analysis 2018

UCDAVIS ANIMAL SCIENCE

"Plant-based meat dollar sales growth has consistently outperformed animal-based meat dollar sales growth"



Approximate Annual Production (US)

200 million lbs plant-based meat

105,000 million lbs animal-based meat

The animal-based and plant-based meat categories grew 45% and 86%, respectively, for the 9-week period ending May 10

Source: Meatingplace – The Analogue Dish, "Sales up, yes, but market share down for alt-meat in retail surge" (May 2020) - 210 Analytics LLC using IRI data

https://www.gfi.org/images/uploads/2020/05/GFI-Covid-19andthePlantBasedMarket.pdf

“US ground beef sales up $1 billion in 2020”

UCDAVIS ANIMAL SCIENCE

LIVESTOCK

U.S. Ground Beef Sales Up $1 Billion In 2020

by Greg Henderson 11:11AM May 27, 2020

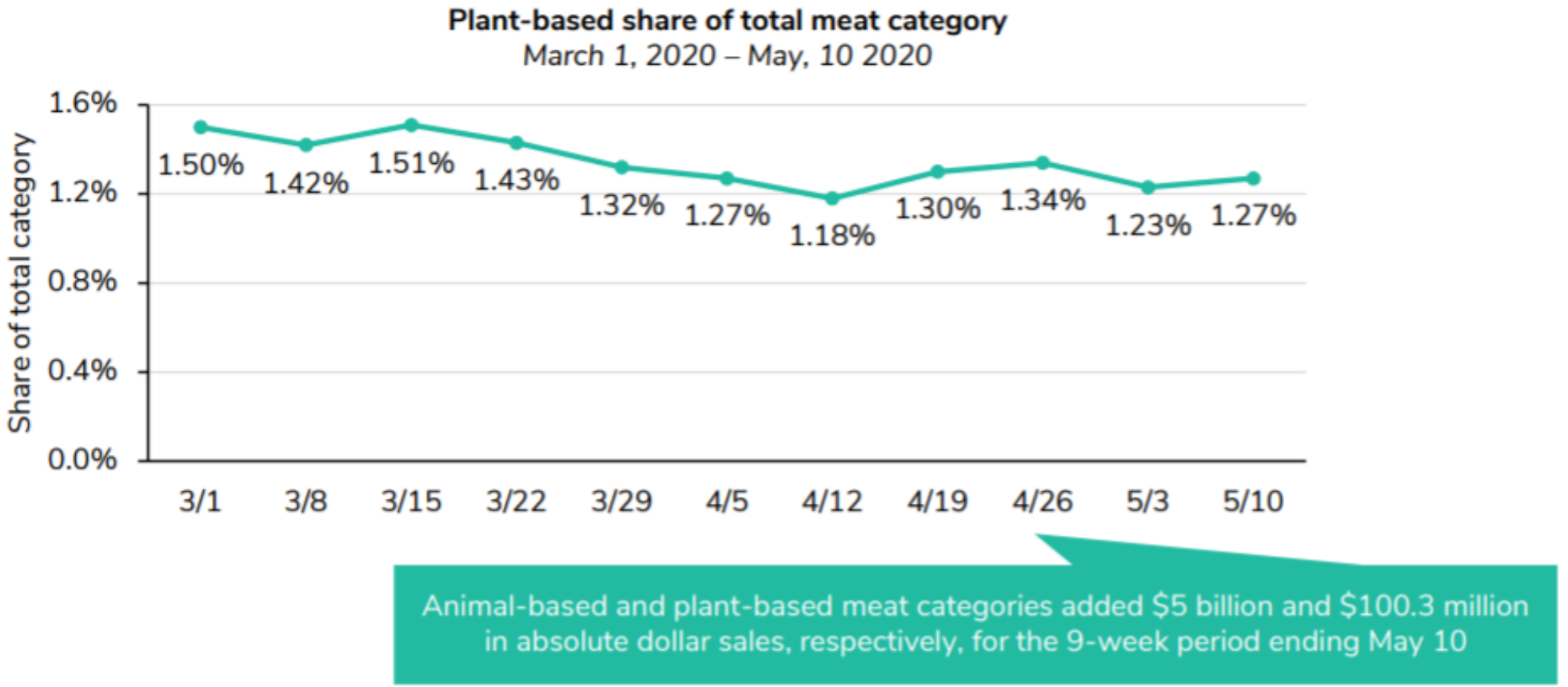
Ground beef sales have increased
(FJ)

“Year-to-date through May 17 (2020), meat department dollar sales were up 24.8%, boasting double-digit growth for ten weeks running. This reflects an additional **$5.5 billion** sold versus the same time period in 2019.

Year-to-date volume sales through May 17 were up 18.0% over the same period in 2019, reflecting an additional **7.6 billion pounds** of meat and poultry sold versus the same time period in 2019.”

https://www.agweb.com/article/us-ground-beef-sales-1-billion-2020

Plant-based meat share has dropped slightly due to absolute gains in animal-based meat dollar sales



Source: Meatingplace – The Analogue Dish, "Sales up, yes, but market share down for alt-meat in retail surge" (May 2020) - 210 Analytics LLC using IRI data

https://www.gfi.org/images/uploads/2020/05/GFI-Covid-19andthePlantBasedMarket.pdf

Are there data available to make an evidence-based assessment of end-product improvement? PRICE

Product:	Ingredients:
Beyond Burger (4 ounces) **$8.99/lb ($.56/oz)**	Water, Pea Protein Isolate*, Expeller-Pressed Canola Oil, Refined Coconut Oil, Rice Protein, Natural Flavors, Cocoa Butter, Mung Bean Protein, Methylcellulose, Potato Starch, Apple Extract, Pomegranate Extract, Salt, Potassium Chloride, Vinegar, Lemon Juice Concentrate, Sunflower Lecithin, Beet Juice Extract (for color), Carrot.
Impossible burger **$12/lb (0.75/oz)**	Water, Soy Protein Concentrate, Coconut Oil, Sunflower Oil, Natural Flavors, 2% or less of: Potato Protein, Methylcellulose, Yeast Extract, Cultured Dextrose, Food Starch Modified, Soy Leghemoglobin, Salt, Soy Protein Isolate, Mixed Tocopherols (Vitamin E), Zinc Gluconate, Thiamine Hydrochloride (Vitamin B1), Sodium Ascorbate (Vitamin C), Niacin, Pyridoxine Hydrochloride (Vitamin B6), Riboflavin (Vitamin B2), Vitamin B12.
Beef: **$4-8/lb (.25-0.5/oz)**	Beef, ground, 80% lean meat / 20% fat, raw

https://kbaked.com/2020/01/06/is-beyond-meat-healthy-is-impossible-meat-healthy-is-that-even-the-point/

UCDAVIS
ANIMAL SCIENCE

Are there data available to make an evidence-based assessment of end-product improvement? NUTRITION

Van Eenennaam 6/11/2020

UC DAVIS ANIMAL SCIENCE

Nutritional attributes of Beyond Burger, Impossible Burger and Beef Burger (84% lean)

Attribute	Beyond Burger	Impossible Burger	Beef Burger (84% Lean)
Protein	20 g	19 g	21 g
Total Fat:	18 g	14 g	18
Saturated Fat	6 g	8 g	7 g**
Cholesterol:	0 mg	0 mg	**78 mg**
Total Carbohydrate	**3 g**	**9 g**	0 g
Dietary Fiber	2 g	3 g	0 g
Sugars	0 g	<1 g	0 g
Minerals:			
Copper	?	?	0.075 mg (8%)
Calcium	104 mg* (8% DV)	170 mg (15%)	18 mg (1%)
Iron	4.5 mg* (25% DV)	4.2 mg (25%)	2.33 mg (13%)
Magnesium	?	?	20 mg (5%)
Potassium	300 mg (6%)	610 mg (15%)	328 mg (7%)
Phosphorus	?	180 mg (15%)	191 mg (15%)
Selenium	?	?	17.7 mcg (32%)
Sodium	**390 mg (16%)**	**370 (16%)**	75 mg (3%)
Zinc	?	5.5 mg (50%)	5 mg (45%)

Attribute	Beyond Burger	Impossible Burger	Beef Burger (84% Lean)
Vitamins:			
Thiamin	?	28.3 mg (2350%)	0.047 mg (4%)
Riboflavin	?	0.4 mg (30%)	0.071 mg (5%)
Niacin	?	5.3 mg (35%)	5.162 mg (32%)
Pantothenic Acid	?	?	0.609 mg (12%)
Vitamin B6	?	0.4 mg (25%)	0.386 mg (23%)
Folate	?	115 mcg DFE (30%)	7 mcg DFE (2%)
Choline	?	?	68.1 mg (12%)
Vitamin B12	?	3 mcg (130%)	2.45 mcg (102%)

* Amount calculated from Daily Value listed on label.
** Based on fatty acids, which comprise roughly 90% of weight of fats.

https://www.consumerlab.com/answers/beyond-burger-vs-impossible-burger-vitamins-minerals-comparison/beyond-burger-impossible-burger/ Van Eenennaam 6/11/2020

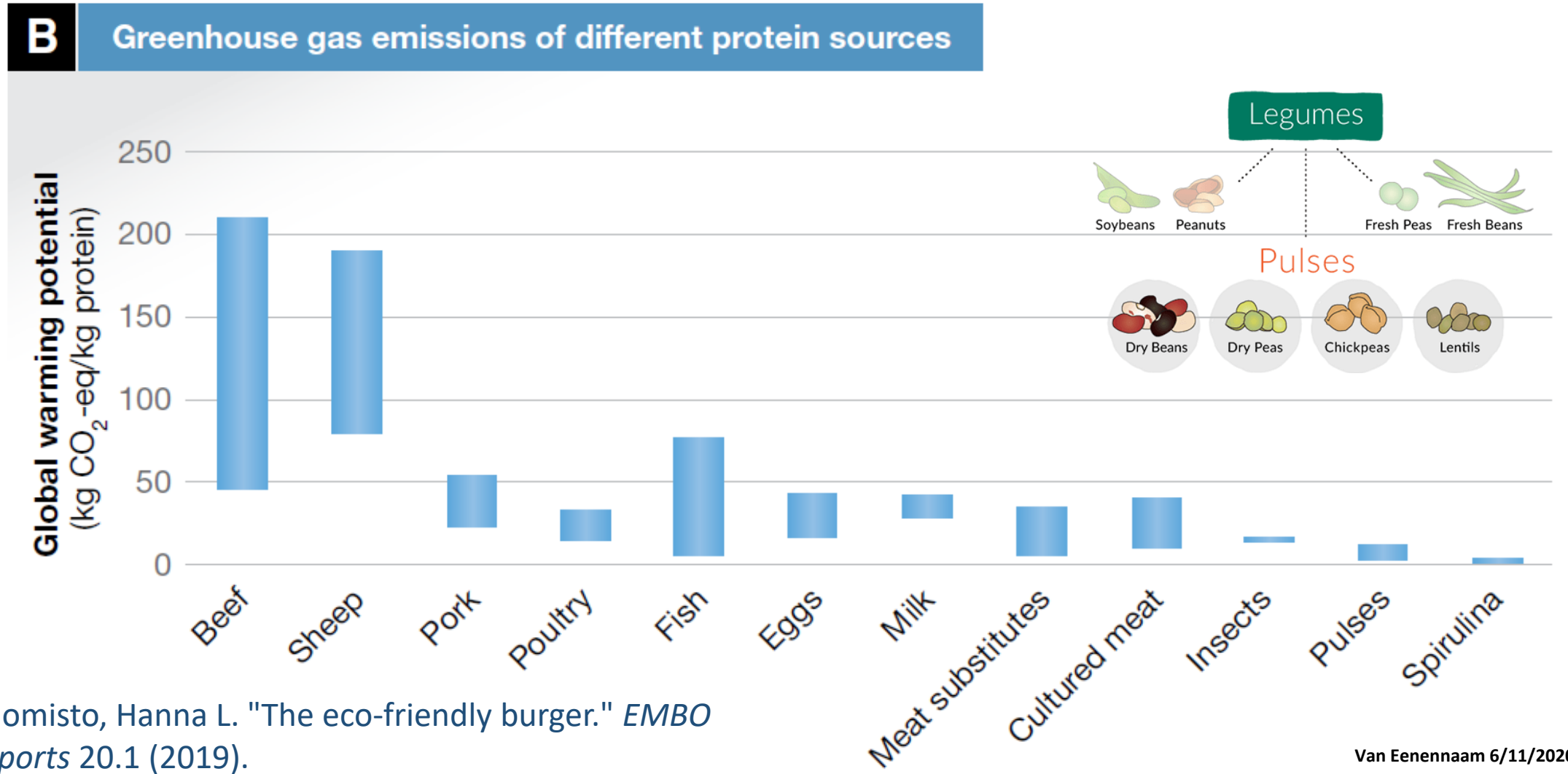
UCDAVIS ANIMAL SCIENCE

Are there data available to make an evidence-based assessment of end-product improvement? SUSTAINABILITY

Product (Number of studies)	per kg product (not necessarily nutritionally equivalent)			
	Carbon Footprint (CO_2-eq)	Land use (m^2)	Energy Use (MJ)	Reference
Beef (15)	9-129 **30.6** 30.5-33	**7-420** **62** **92-113**	**78.6-92.6**	(Nijdam et al., 2012) **Qantis*** (Mattick, 2018)
Mutton/lamb (4)	10-150	**20-33**		(Nijdam et al., 2012)
Milk (12)	1-2	**1-2**		(Nijdam et al., 2012)
Pigs (8)	4-11 **9** 4.1-5	**8-15** **16-18**	**16-19.6**	(Nijdam et al., 2012) **Qantis*** (Mattick, 2018)
Poultry (4)	2-6 **6** 2.3	**5-8** **9.5**	**26.6**	(Nijdam et al., 2012) **Qantis*** (Mattick, 2018)
Eggs (4)	2-6	**4-7**		(Nijdam et al., 2012)
Impossible Burger	3.5	**2.5**		**Qantis***
Soybeans	**2**			**Qantis***
Pulses (2)	1-2	**3-8**		(Nijdam et al., 2012)
Cultured Meat "anticipatory" numbers	1.69 (19% protein) 24 (19% protein) 4-25 (7-19% protein)	**0.2** **.39-.77** **2-8**	**26.64** **290-373** **50-359**	(**Tuomisto** and Teixeira de Mattos, 2011) (Smetana et al., 2015) (Mattick, 2018) (Lynch and Pierrehumbert, 2019)
	"Cultured meat is not prima facie climatically superior to cattle; its relative impact instead depends on the availability of decarbonized energy generation and the specific production systems that are realized."			

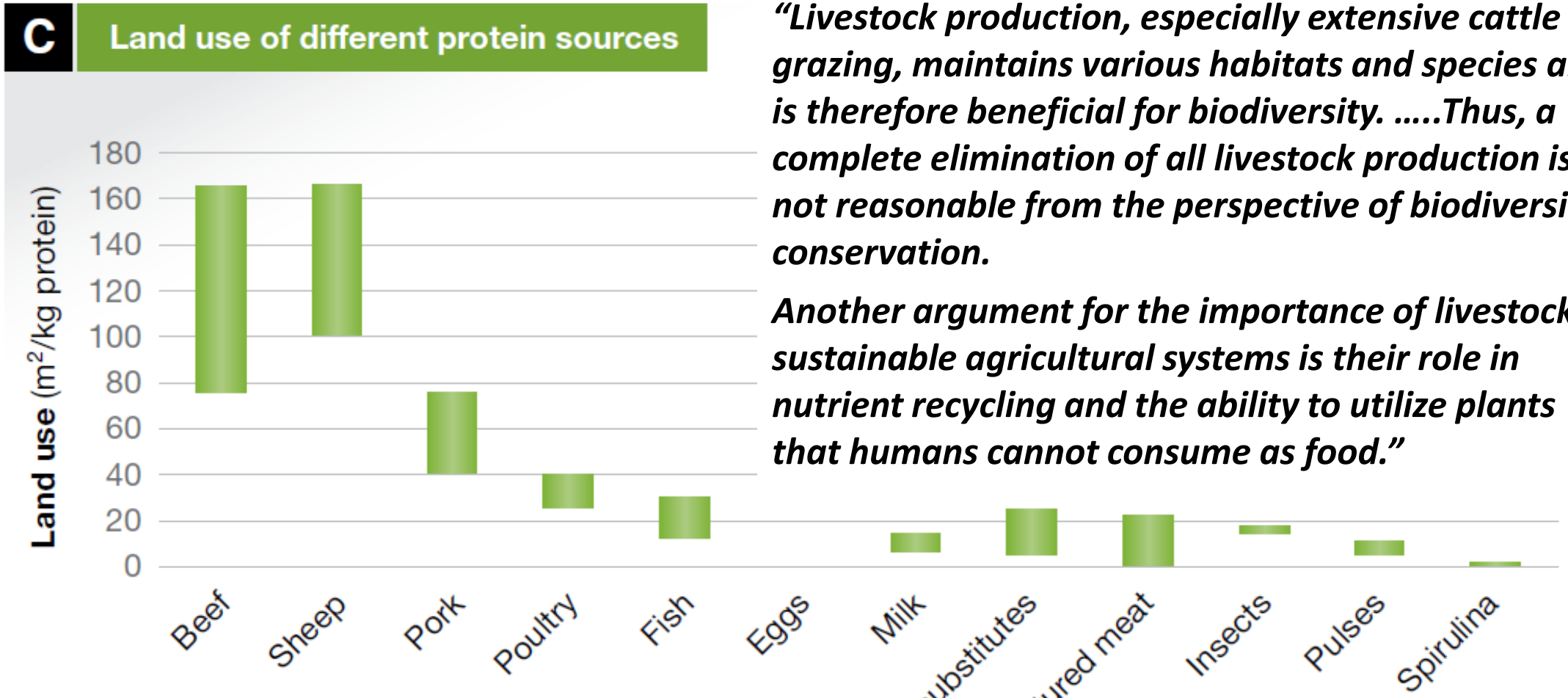
*Quantis is a private company that develops sustainability metrics for their clients https://quantis-intl.com/

The environmental impact of different protein sources: Greenhouse gas emissions



Tuomisto, Hanna L. "The eco-friendly burger." *EMBO reports* 20.1 (2019).

The environmental impact of different protein sources: Land Use

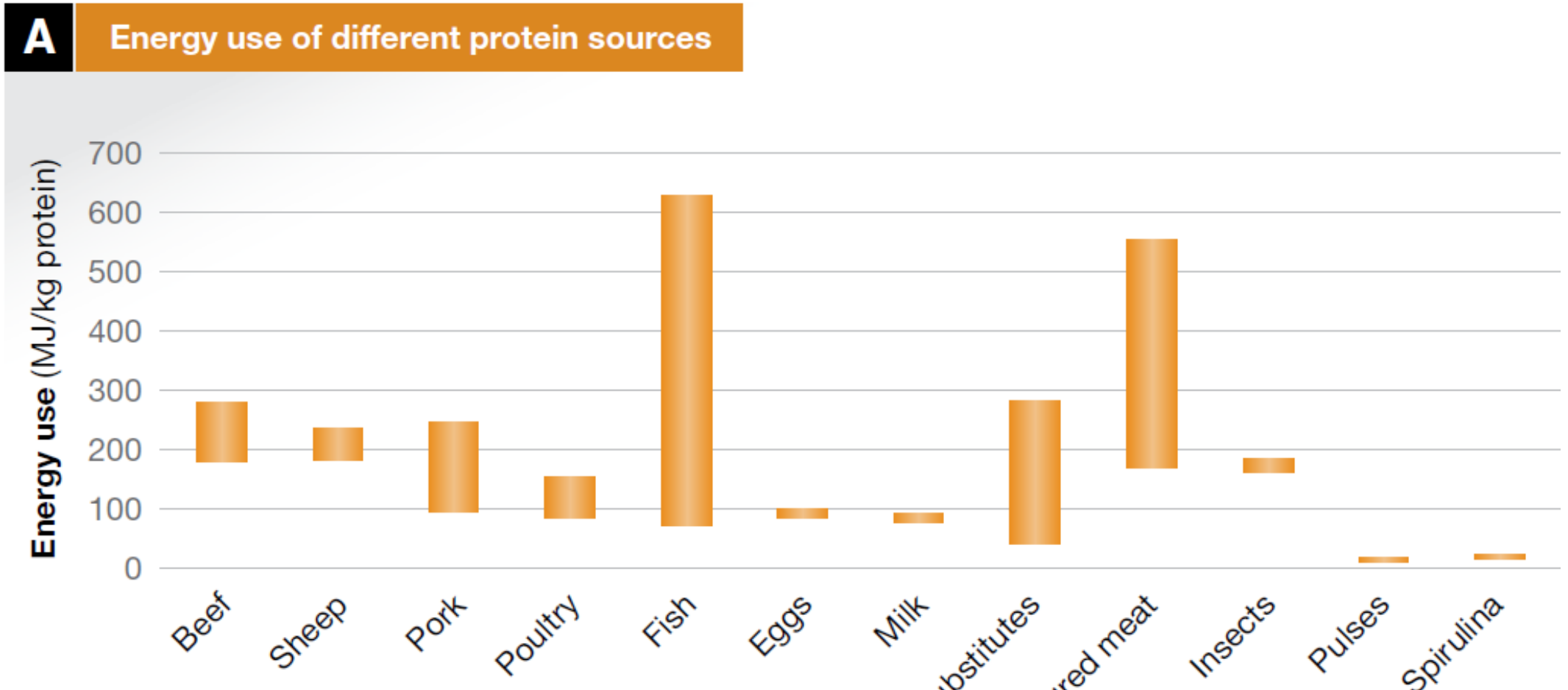


"Livestock production, especially extensive cattle grazing, maintains various habitats and species and is therefore beneficial for biodiversity. …..Thus, a complete elimination of all livestock production is not reasonable from the perspective of biodiversity conservation.

Another argument for the importance of livestock in sustainable agricultural systems is their role in nutrient recycling and the ability to utilize plants that humans cannot consume as food."

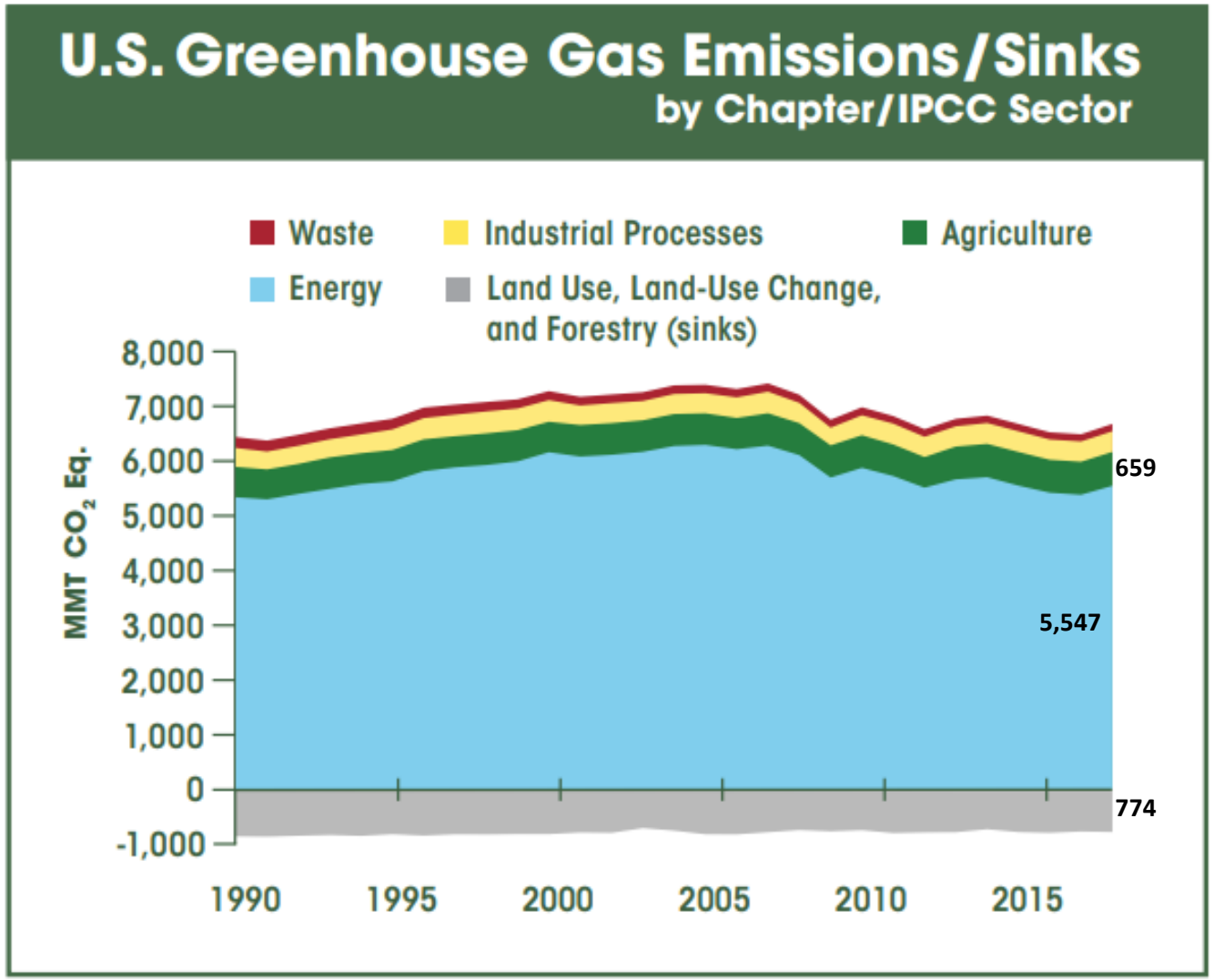
Tuomisto, Hanna L. "The eco-friendly burger." *EMBO reports* 20.1 (2019).

The environmental impact of different protein sources: Energy Use



Tuomisto, Hanna L. "The eco-friendly burger." *EMBO reports* 20.1 (2019).

In the US, agricultural GHG emissions are more than offset by sequestration from the land sector



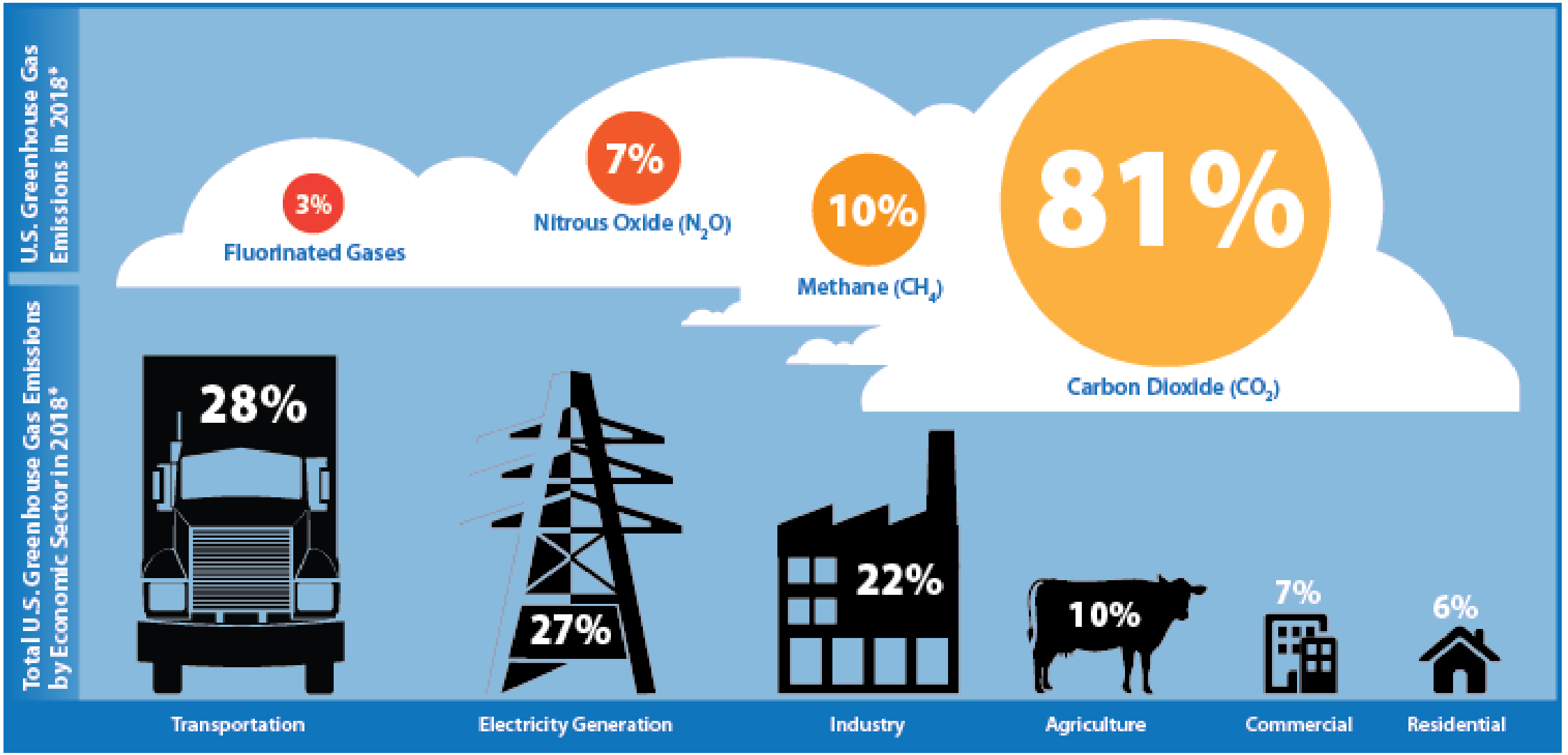
In 2018, U.S. greenhouse gas emissions totaled 6,677 million metric tons of carbon dioxide equivalents, or 5,903 million metric tons of carbon dioxide equivalents after accounting for sequestration from the land sector.

75.4% U.S. carbon dioxide emissions were from fossil fuel combustion

Sequestration from the land sector **774** million metric tons of carbon dioxide equivalents (**12%**) was greater than emissions from the agriculture sector **659** million metric tons of carbon dioxide equivalents (**10%**).

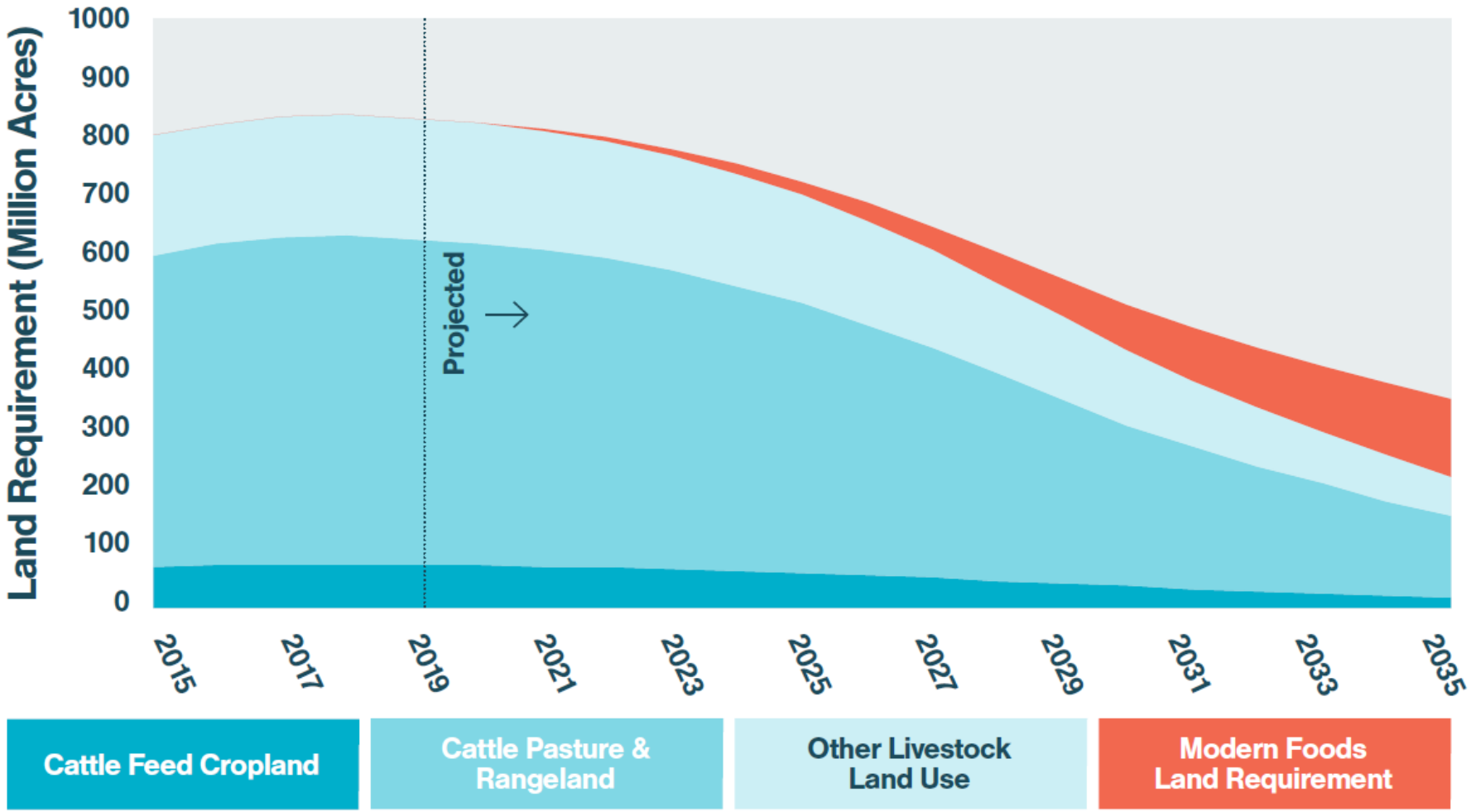
UCDAVIS ANIMAL SCIENCE

What will be the trade-offs associated with replacing agriculture with industrial food production?



What will be the impact of alternative meats?

According to RethinkX: *"The best proxy for land that has no alternative productive use might be ranch land"*



"by 2030, cattle pasture, rangeland, and feed cropland will decline by about 50%. This means the disruption of the U.S. beef and dairy industries by modern production methods will free up about 300 million acres of land by 2035, rising to 450 million acres by 2035."

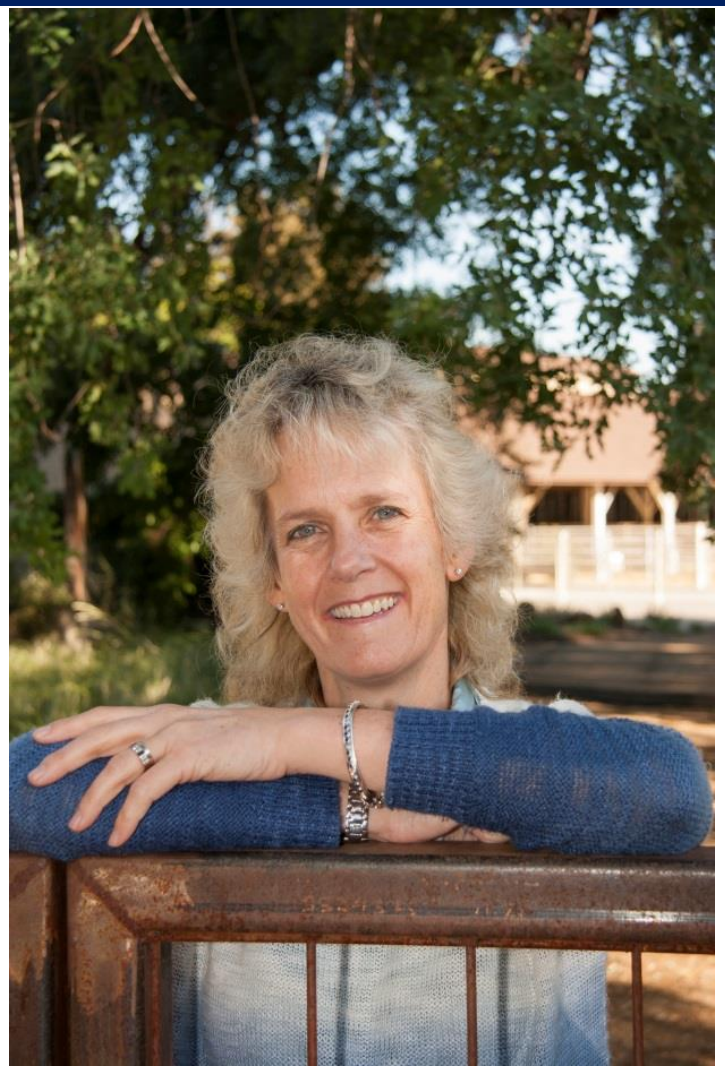
Source: RethinkX *Food+and+Agriculture+Report.pdf (September 2019)* https://www.rethinkx.com/food-and-agriculture

See you in the real world soon!

UCDAVIS
ANIMAL SCIENCE

My laboratory receives public funding support from the National Institute of Food and Agriculture and the Biotechnology Risk Assessment Grant (BRAG) program, U.S. Department of Agriculture, under award numbers 2017-33522-27097, 2018-67030-28360, and 2020-67015-31536.

USDA
United States Department of Agriculture
National Institute of Food and Agriculture



Van Eenennaam 6/11/2020