

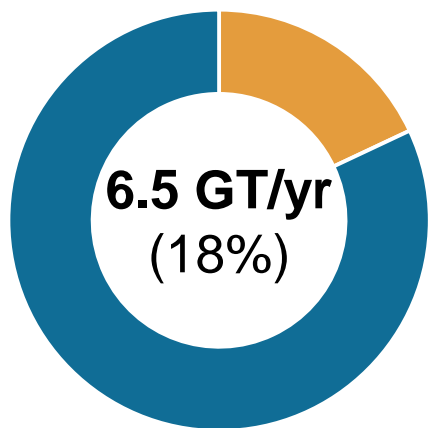


A fork in the road for synthetic meat

Michael Campos, Ph.D.
ARPA-E Fellow

Meat is a carbon-based fuel – and it's popular

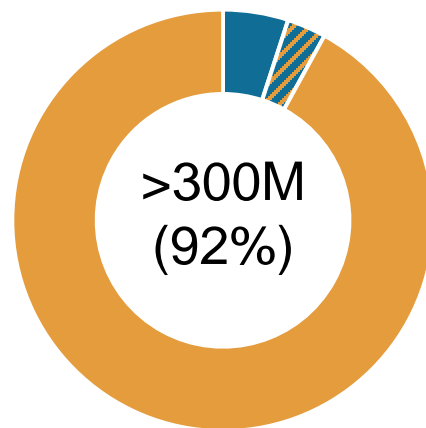
Global GHGs
from livestock



By comparison:

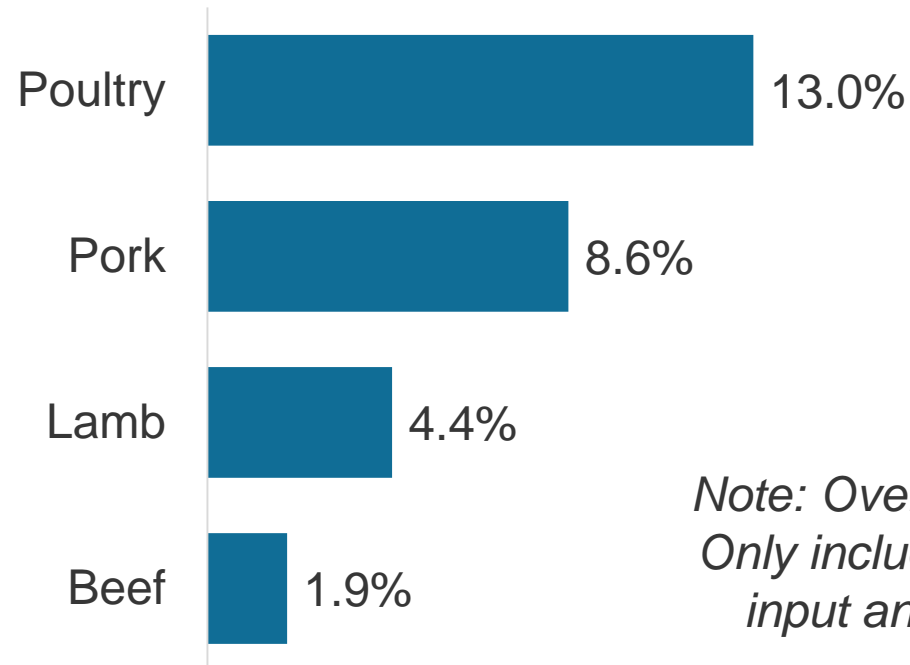
*ALL transportation:
4.7 GT/yr*

Americans
eating meat



*India: 60-70%
(lowest by far)*

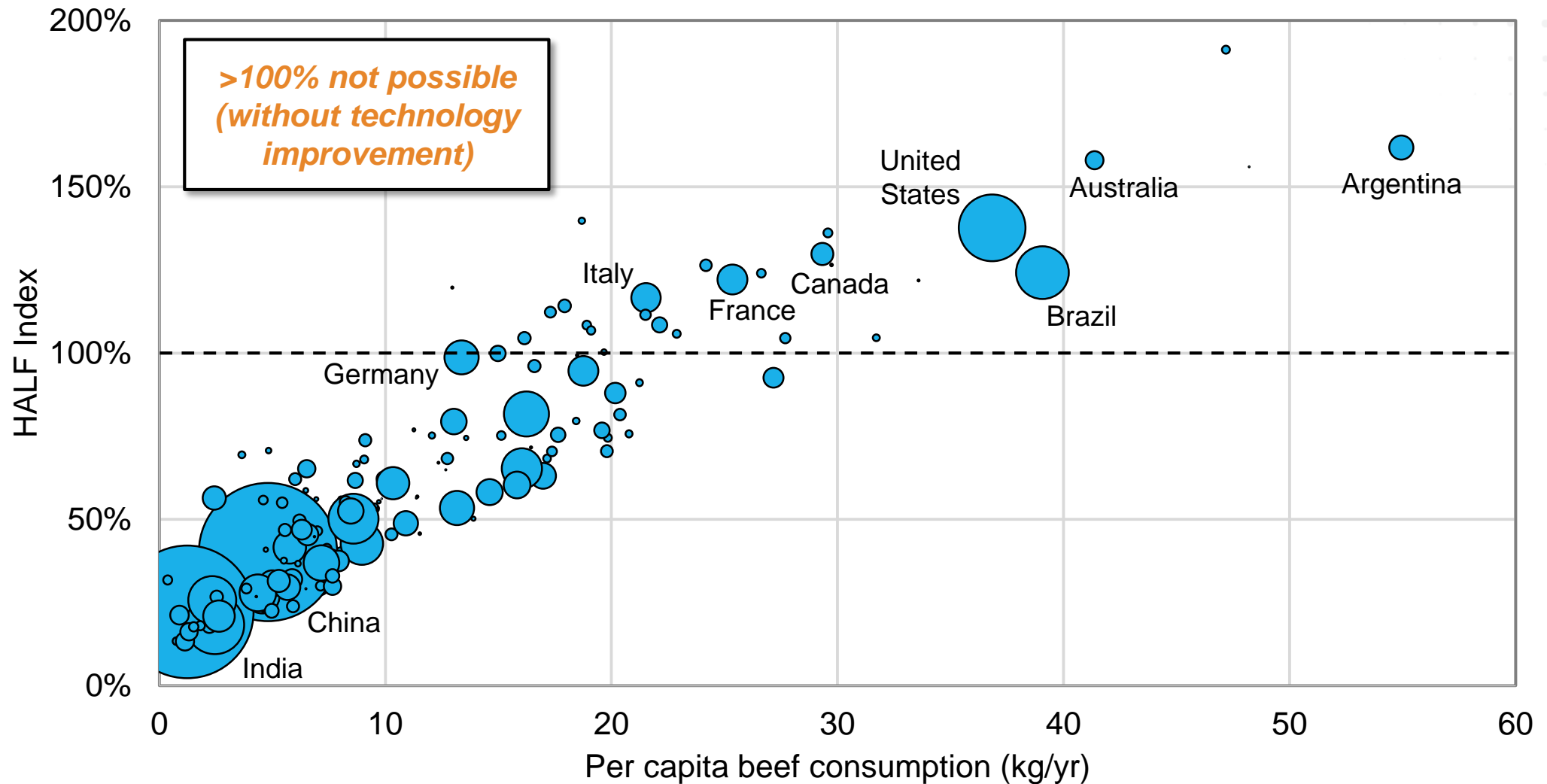
Low energy efficiency



*Note: Overestimates.
Only includes caloric
input and output*

- ▶ Not for today: population growth, land and water use, foodborne illness, antibiotic resistance, ethics, politics

Western-style beef consumption does not scale

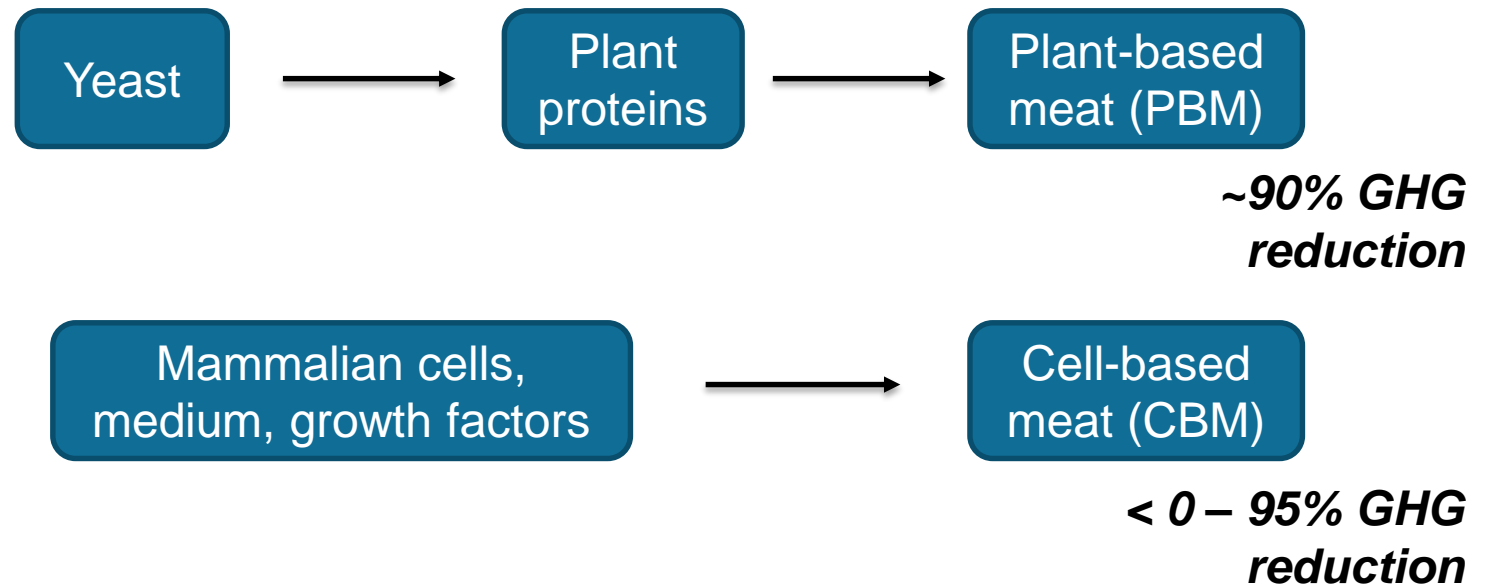


How do you decarbonize AND scale up meat production?



"We shall escape the absurdity of growing a whole chicken in order to eat the breast or wing, by growing these parts separately under a suitable medium."

—Winston Churchill, 1931



The (plant-based) elephant in the room



Impossible Foods

\$687.5M raised

Burger King pilot in progress



Beyond Meat

>\$9B valuation after 2019 IPO

Carried in >15,000 stores

+ many others

- ▶ Excellent engineering
- ▶ Cheap venture capital
- ▶ Strong early sales
- ▶ Buy-in from chefs and celebrities

***Why should ARPA-E
be involved?***

Argument: the current approach won't get the job done

1. Novelty wears off in consumer products
2. Opt-in problem: real burgers on the menu
3. Passing the “Turing Test” is hard

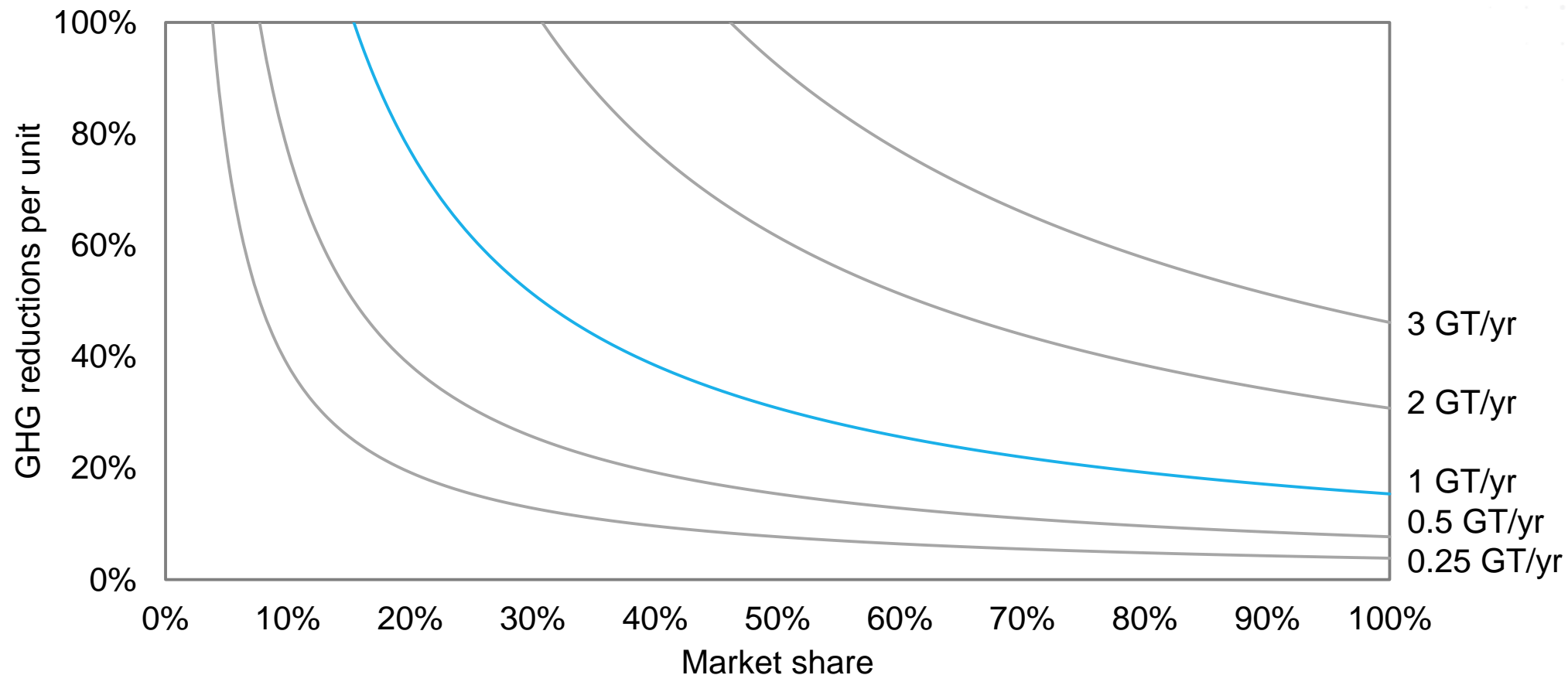
Mountain Pass Sports Bar, Gaylord Rockies

Classic Cheddar Burger*	\$16.00	Impossible Veggie Burger	\$15.00
beef sharp cheddar cheese lettuce tomato pickles brioche bun		garden slaw pepper jack Rockies sauce sesame brioche bun	
Smokehouse Turkey BLT Wrap	\$14.00	Spicy Fried Chicken Sandwich*	\$16.00
grilled tomato aioli spinach wrap		sriracha aioli pickles sesame potato roll	
Miso Seared Salmon Sandwich*	\$17.00	Citrus-Chili Pork Tacos	\$14.00
sriracha aioli carrot ginger coleslaw brioche bun		pickled red onion cilantro flour tortilla	



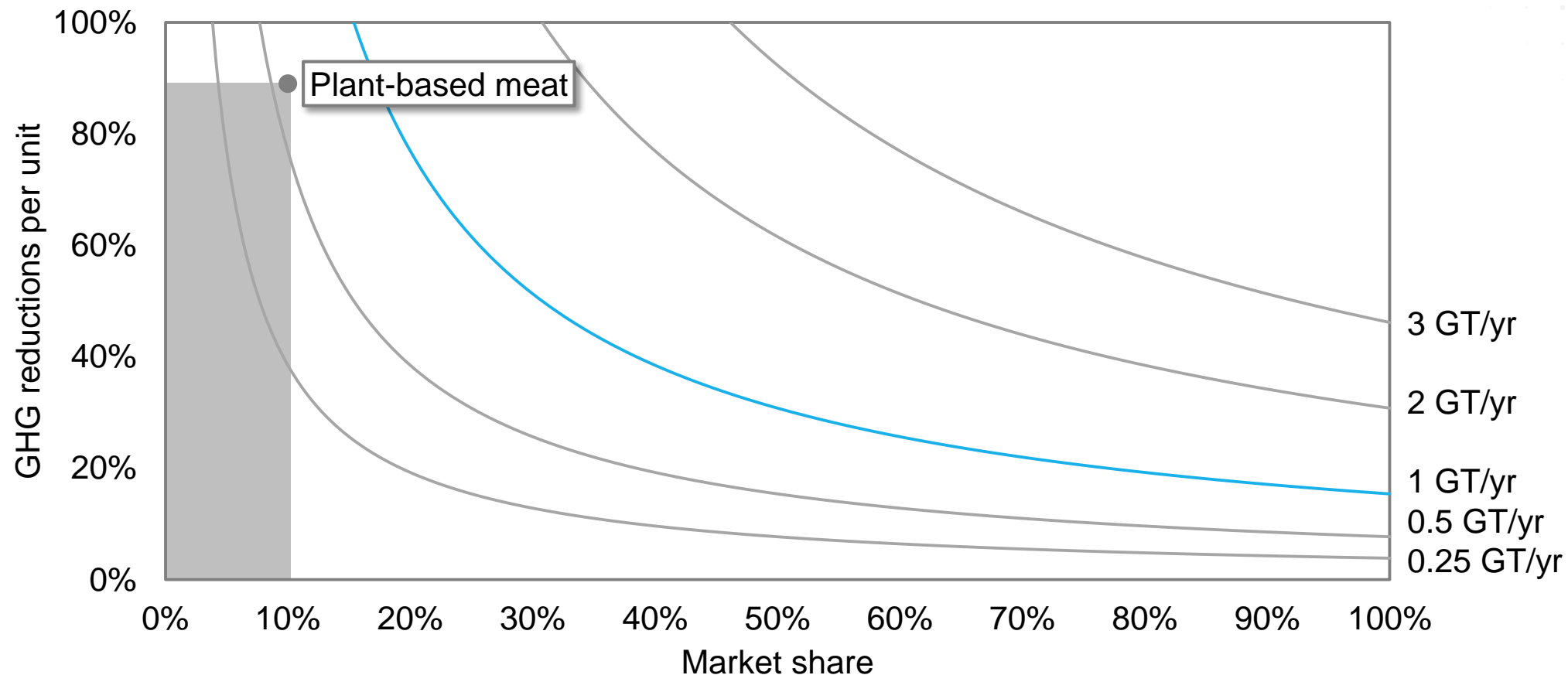
How to avoid a gigaton per year

GHG reductions = GHG reductions per unit × Market share



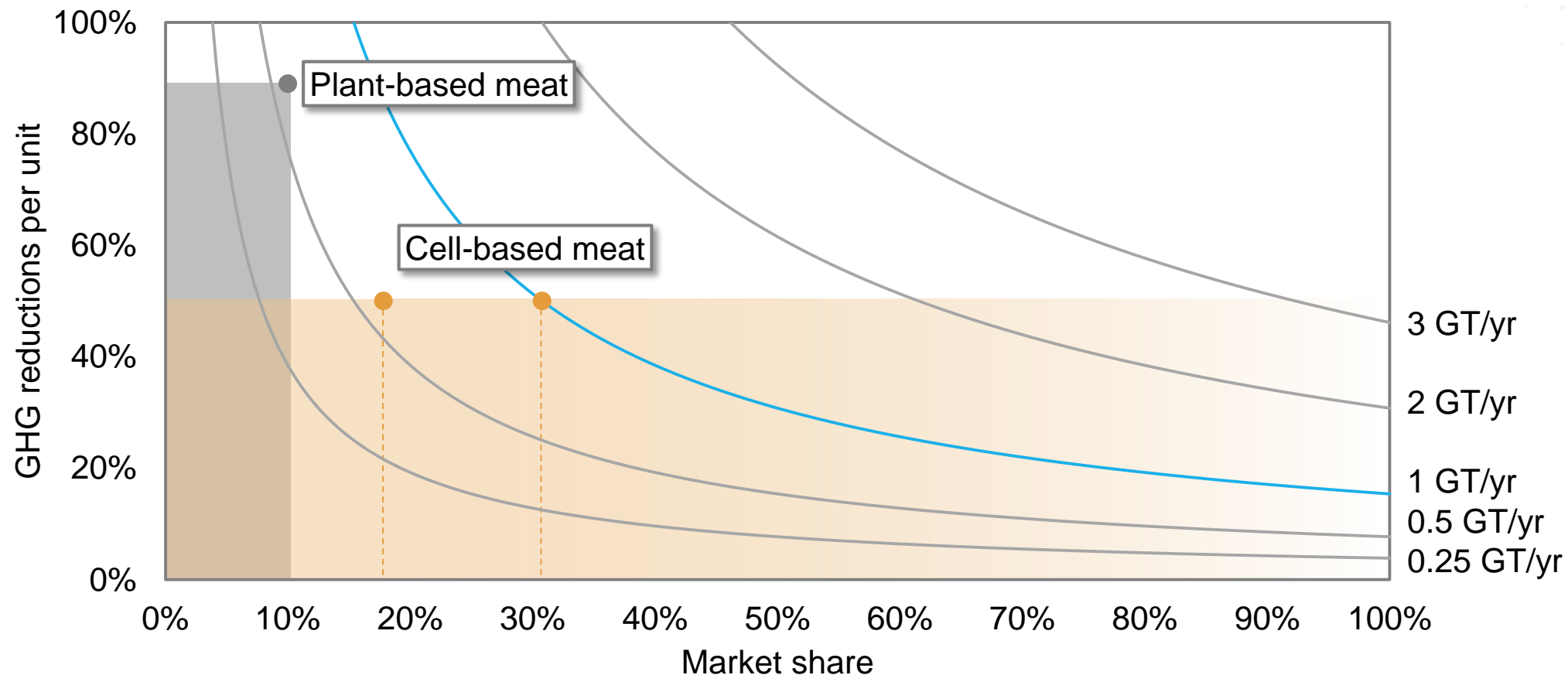
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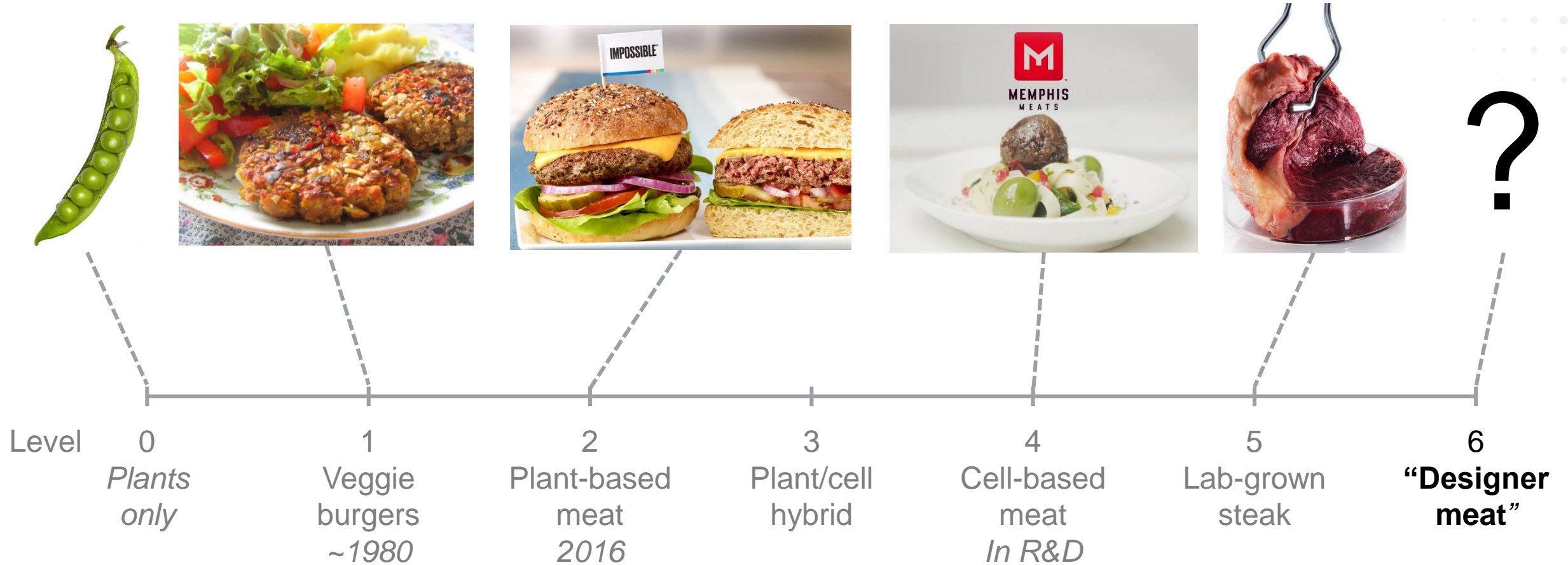


How to avoid a gigaton per year

GHG reductions = GHG reductions per unit × Market share



Shooting for “Level 6”



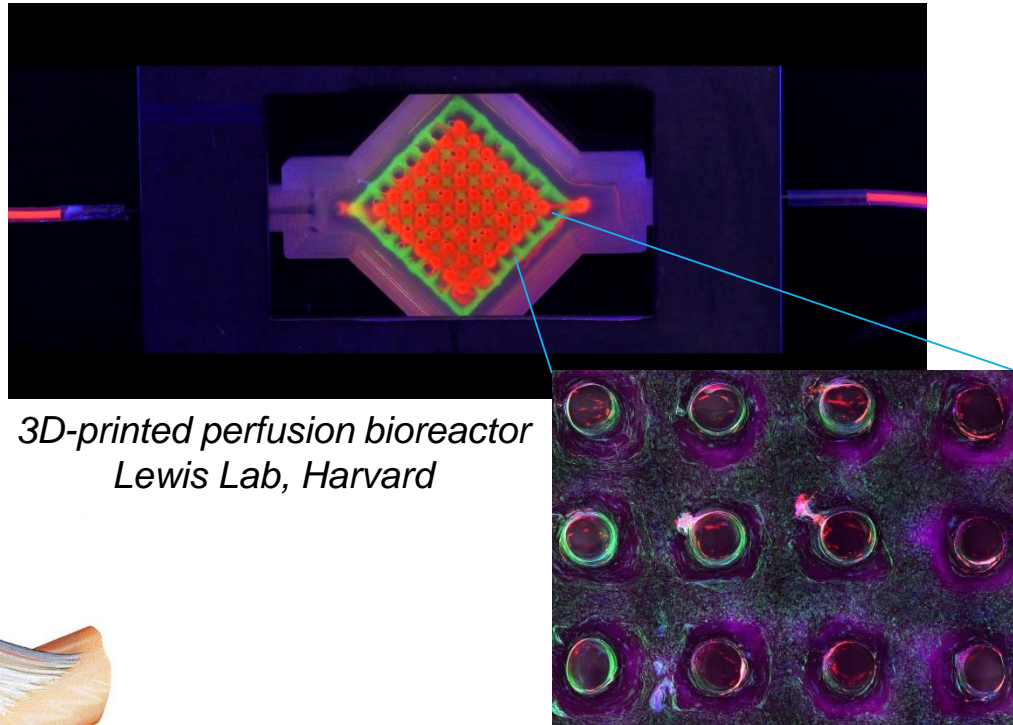
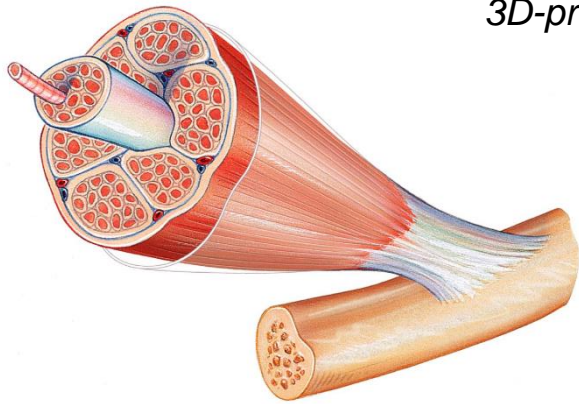


The world needs to crave it

1. Ruthlessly optimized flavors, textures, nutritional profiles, production methods
2. Stands on its own: not “green,” “sciencey,” “just as good,” or inconvenient
3. Cost parity or advantage

Innovations needed: Bioreactor design

- ▶ How do you grow complex superstructures rapidly and delicately?
- ▶ Draw upon reactor bed design, mesoporous material design, flow path design

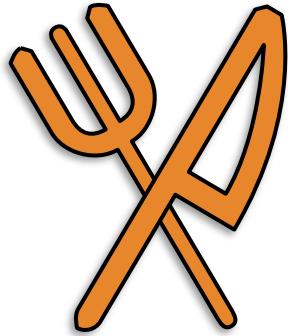


*3D-printed perfusion bioreactor
Lewis Lab, Harvard*



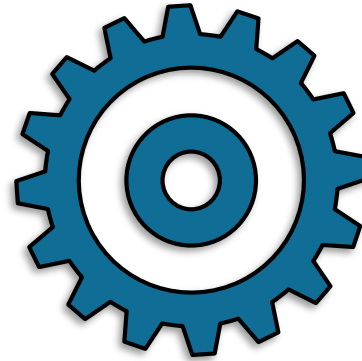
- Concurrent innovations needed:
- ▶ Inexpensive medium development
 - ▶ Improved life cycle assessments
 - ▶ Novel product designs

This is could be a win-win-win



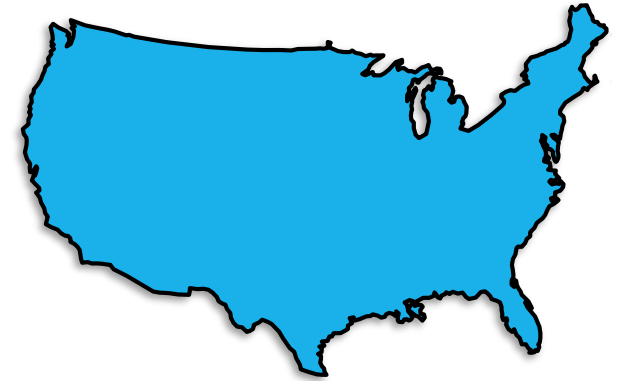
Consumer

Superior products
Real meat
Designer features



Agricultural Industry

Demand for feedstocks
Sustainable land use
Spillover effects



US

Export position
Military supply chain
Decarbonization

We want your feedback!

- ▶ How would YOU design a bioreactor to grow complex structures?
- ▶ What properties should product designers prioritize?
- ▶ What tissue engineering knowledge can and can't be leveraged?
- ▶ What should LCAs look like at scale?
- ▶ What other energy-relevant materials should be grown this way?

- ▶ **Get in touch:**
 - Text in questions
 - After this session
 - Coffee with ARPA-E: 8 am tomorrow
 - Email: michael.campos@hq.doe.gov

▶ **Thank you!**