Good Food Institute

A summary of recommended stakeholder actions

Anticipatory life cycle assessment and techno-economic assessment of commercial cultivated meat production

MARCH 09, 2021

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Executive summary

A life cycle assessment (LCA) and techno-economic assessment (TEA)[1] modeling a future large-scale cultivated meat[2] production facility show that by 2030, cultivated meat could have reduced overall environmental impacts, a lower carbon footprint, and be cost-competitive with some forms of conventional meat. This is generally true whether cultivated meat is produced using conventional energy mixes or renewable energy, but the reduction in environmental impacts and carbon footprint is greatest when cultivated meat is produced using renewable energy. In addition to the degree to which renewable energy is sourced at future facilities and the degree of decarbonization throughout the supply chain, the key factors that accomplish these outcomes are maintaining high-density cell cultures, efficiently using and sourcing cell culture media, and relaxing payback times for facility capital costs.

The LCA and TEA reports are the first of their kind to be informed by data inventories collected from active industry partners—over 15 companies involved in the cultivated meat supply chain, including five cultivated meat manufacturers contributed data and expertise. The study design, data analysis, and writing of the reports was performed independently by CE Delft.

The LCA accounts for uncertainty in the cultivated meat production process by conservatively assuming high energy use at the facility. Despite this conservative estimate, the LCA shows that even when compared to an extremely optimistic benchmark projecting reduced environmental impacts of conventional animal agriculture by 2030, cultivated meat produced using renewable energy:

- Reduces global warming impacts by 17%, 52%, and 85-92% compared to conventional chicken, pork, and beef production, respectively.[3]
- Is 3.5x more efficient than conventional chicken at converting feed into meat, consequently reducing land use by 63%, 72%, and 81-95% compared to conventional chicken, pork, and beef production, respectively.
- Can be cost-competitive, with production costs modeled as low as $5.66 per kilogram ($2.57 per pound).

While the reports aim to reflect how cultivated meat may be produced in the year 2030, data gaps persist and assumptions may change over the next decade as the nascent cultivated meat industry matures. The findings in these reports should not be interpreted as representing unchanging truths or

[1] Read the LCA and TEA reports from CE Delft (www.cedelft.eu). LCA (https://www.cedelft.eu/en/publications/2610/lca-of-cultivated-meat-future-projections-for-different-scenarios) and TEA (https://www.cedelft.eu/en/publications/2609/tea-of-cultivated-meat-future-projections-of-different-scenarios).
[2] Cultivated meat is genuine animal meat or seafood produced by directly cultivating animal cells. To learn more about cultivated meat, visit (https://gfi.org/science/the-science-of-cultivated-meat/).
[3] The favorable results from these conservative comparisons indicate that the environmental benefits of cultivated meat are expected to be highly robust.

the absolute lower boundaries for the costs and climate impacts of cultivated meat. However, the insights from these reports should be used to effectively address existing technical and economic bottlenecks[4] and serve as guidance for stakeholders to further the adoption of cultivated meat.

Key stakeholders such as governments, investors, nonprofits, and other policymakers can develop an ecosystem that fosters innovation, supports the deployment of cultivated meat, and capitalizes on its potential to mitigate massive global challenges related to climate change, antibiotic resistance, and other areas of human, animal, and planetary health. To achieve this, we recommend stakeholders to:

- Significantly increase investments in open-access R&D.
- Enact science-based policies for capitalizing on the carbon opportunity of land use.
- Incentivize new infrastructure.
- Develop a robust and equitable workforce for the cultivated meat industry.

We additionally highlight commendable actions already being taken within the cultivated meat industry and point to examples from other sectors and published studies that may inform the best path forward. These reports collectively highlight the enormous potential for cultivated meat as being a sustainable and affordable protein option for a growing population.

Cultivated meat cost and efficiency

Production cost (model low end)	**$5.66/kg** **$2.57/lb**	**Input efficiency** (compared to ambitious benchmarks for conventional chicken)	**3.5x**

Cultivated meat environmental impact comparison (when produced via renewable energy)

	Cultivated meat compared to ambitious benchmarks for conventional chicken	Cultivated meat compared to ambitious benchmarks for conventional pork	Cultivated meat compared to ambitious benchmarks for conventional beef
Global Warming	**17% reduction**	**52% reduction**	**Up to 92% reduction**
Land Use	**63% reduction**	**72% reduction**	**Up to 95% reduction**

[4] For more on technical bottlenecks and future directions, read our technical summary (https://gfi.org/wp-content/uploads/2021/03/cultured-meat-LCA-TEA-technical.pdf).

Table of contents

Study design

The life cycle assessment (LCA) and techno-economic assessment (TEA) model a hypothetical commercial-scale cultivated meat production facility operating in the year 2030. The facility is capable of annually producing 10 kilotons of minced cultivated meat (like hamburger or ground turkey).[5] To build the model, inventory data were obtained from 15 different companies active in the cultivated meat supply chain, including five cultivated meat manufacturers.

The LCA considered all inputs and outputs upstream of the product leaving the facility. In the LCA, two energy mixes were modeled for cultivated meat production: a conventional energy mix based on stated policies for 2030 and a sustainable energy mix produced with 50% solar, 50% on-shore wind, and heating derived from geothermal heat.

For conventional meat production, an intensive, West-European system that is significantly below global averages for carbon footprint was assumed.[6] To represent ambitious improvements in environmental impacts for conventional meat production by 2030, various assumptions were made: sustainable energy would be deployed at farm and feed production facilities, there would be reduced ammonia emissions through increased outdoor grazing, reduced methane emissions obtained through feed additives, and no land-use change associated with soy used in feed. **These assumptions further reduce the carbon footprint of conventional beef by 15%, pork by 26%, and chicken by 53%.** These ambitious benchmarks were set to ensure robust conclusions could be drawn from environmental impact comparisons.

The TEA considered the capital expenditures (equipment and installation costs) and operating costs (electricity, heat, water, labor, media, and other inputs) that contribute to the cost of cultivated meat production. All equipment in the facility was assumed to be food-grade rather than pharmaceutical-grade, and process costs were benchmarked to the food sector. Cost estimates were given uncertainty ranges from -20% to +40%.

The study design, data analysis, and creation of the model facility was performed independently by CE Delft. For more details on the study design, we refer the reader to the LCA and TEA reports.

[5] Note that the terminology "cultivated meat" includes seafood and organ meats (e.g., foie gras).
[6] Poore and Nemecek, 2018. See page 28 of the LCA report for further details.

Key findings and insights

The LCA and TEA collectively show that by 2030 cultivated meat could have reduced overall environmental impacts, a lower carbon footprint, and be cost-competitive with some forms of conventional meat. The key takeaways from the LCA (summarized in Table 1) and TEA are listed below, with subsequent follow-on action-oriented recommendations discussed later.

Eating this form of meat	instead of this conventional meat	reduces this environmental impact category by approximately this much			
		Particulate Matter Pollution[7]	Global Warming[8]	Human Toxicity[9]	Land Use
Cultivated meat (sustainable energy)	Beef (cattle)	93%	92%	92%	95%
	Beef (dairy)	85%	85%	89%	81%
	Pork	49%	52%	47%	72%
	Chicken	29%	17%	-2%	63%
Cultivated meat (conventional energy)	Beef (cattle)	90%	55%	92%	94%
	Beef (dairy)	79%	22%	89%	79%
	Pork	29%	-258%*	50%	70%
	Chicken	1%	-445%*	4%	60%

Table 1. Reproduced from Table 5 in the LCA report. Numbers represent the percentage change from the cultivated meat sustainable energy scenario. The environmental impact score is driven by Particulate Matter Formation (47% of score), Global Warming (33% of score), Human Toxicity (10% of score), and Land Use (6% of score), with other categories making up the remaining 4%. *The LCA conservatively assumes high energy use at the cultivated meat facility, which is representative of an upper estimate (see Technical Summary).[10] Conventional meat production is modeled as an optimized form of production, which has a significantly reduced carbon footprint compared to global production averages (see Study Design and Figure 3 of the LCA report).

[7] Particulate matter formation refers to the mixture of solid particles and liquid droplets found in the air. It is quantified in terms of kg $PM_{2.5}$-eq and can be thought of more simply as air pollution. For animal agriculture, particulate matter formation is driven primarily by ammonia from manure and fertilizer use. For cultivated meat, it is driven by the creation of sulfur dioxide and other fine particulates from electricity generation, raw material mining, and feedstock processing upstream in the supply chain. Refer to Figure 13 of the LCA report for further details.

[8] Measured in kg CO_2-eq. For comparison to conventional beef production, cultivated meat's global warming benefits are best viewed as short-term, as beef's impacts are driven primarily by methane.

[9] Human toxicity is a metric that expresses the potential harm of a unit of chemical released into the environment. It is quantified in terms of kg 1,4DCB-eq (DCB being dichlorobenzene). For animal agriculture, it is driven primarily by manufacturing and application of fertilizers and pesticides. For cultivated meat, human toxicity is driven by mining and raw material processing for electricity production and infrastructure, as well as fertilizer and pesticide use for raw materials (i.e., soy, corn) used in the cell culture medium. To learn more about human toxicity potential, see (https://core.ac.uk/download/pdf/52101237.pdf).

[10] (https://gfi.org/wp-content/uploads/2021/03/cultured-meat-LCA-TEA-technical.pdf).

1. **Reduced environmental impacts:** Even when compared to an extremely optimistic scenario projecting reduced environmental impacts of conventional animal agriculture by 2030, cultivated meat produced using renewable energy outperforms all forms of conventional meat production in cumulative environmental impacts (including air pollution, land use, and carbon footprint).[11] Cultivated meat can reduce global warming impacts by 17%, 52%, and 85-92% compared to conventional chicken, pork, and beef production, respectively. Given the conservative comparisons in the LCA, the reduced environmental impacts of cultivated meat are expected to be highly robust.

2. **Fewer inputs required:** Cultivated meat is 3.5x more efficient than conventional chicken (the most efficient form of conventional meat production) at converting feed into meat. Consequently, cultivated meat reduces land use by 63%, 72%, and 81-95% compared to conventional chicken, pork, and beef production, respectively. If substitution of cultivated meat instead of conventional meat occurs in diets, the reclaimed land can be restored and rewilded to sequester more carbon or repurposed for renewable energy or human food production, increasing cultivated meat's environmental and food security benefits.

3. **Cost competitive: Modeled as low as $5.66 per kg ($2.57 per pound), cultivated meat could compete with some conventional meats on costs by 2030.** The LCA and TEA analyzed the production of a ground meat product containing 100% cultivated meat. However, many manufacturers are looking at using cultivated meat as an ingredient in plant-based or cultivated blends as a way to more thoroughly biomimic the conventional animal meat experience. Blended or "hybrid" products are anticipated to have reduced costs and environmental impacts, but further analyses are needed to confirm this.

4. **A need for new infrastructure:** The model facility producing 10 kilotons of cultivated meat annually has an estimated cost of $450M USD. Relaxed payback time criteria over the lifetime of the facility will be critical to obtaining competitive prices for cultivated meat. A menu of financing strategies and incentives will need to be made available to install new infrastructure at all scales. The TEA highlights the large business opportunity to develop and manufacture more affordable, fit-for-purpose cultivators for cultivated meat production.

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[11] Environmental impacts were measured by calculating the carbon footprint expressed in greenhouse gas equivalents and the ReCiPe Endpoint and Midpoint methods, a metric that tallies 18 different environmental impact categories into a single score. ReCiPe was developed by the Dutch government as a means to improve life cycle analyses. To learn more, see (https://www.leidenuniv.nl/cml/ssp/publications/recipe_characterisation.pdf).

5. **Government support of cultivated meat will create new high paying job opportunities in both rural and urban areas.** The TEA finds that the model facility is expected to provide approximately 130 to 200 high-paying jobs, depending on its process efficiencies, with other opportunities becoming available elsewhere in the supply chain. Cultivated meat can be produced in facilities located in rural and urban areas. The selection of a facility's location will likely be dependent in part by access to renewable energy or ease of generating renewable energy, access to raw materials (e.g., glucose from corn and amino acids from soy used in cell culture media), access to specialized labor and distribution channels, and final facility size.

6. **Further cost and environmental impact reductions are possible:** The LCA and TEA studies analyzed sets of favorable but realistic scenarios that decrease the costs and environmental impact from a baseline cultivated meat production scenario with a specified set of assumptions. These studies should not be interpreted as representing absolute lower boundaries for costs or climate impacts. Rather, they should be used as a roadmap for identifying potential improvements outside of what has been analyzed. These include the creation of more efficient or automated cultivation processes, cell culture medium recycling, improved efficiencies and methods of production for growth factors, and the importance of sourcing or generating affordable renewable energy. These and other technology development opportunities are further discussed in our sister summary for technical audiences.[12]

7. **The commercial success of cultivated meat has additional benefits.** While important, a narrow focus on emissions can miss out on other positive externalities that accompany cultivated meat if it succeeds in the marketplace and substitutes for conventional meat in diets. These benefits include mitigation of antibiotic resistance, foodborne illness, and zoonotic disease risk associated with conventional animal agriculture, restoration of terrestrial and marine habitats, and a decreased rate of biodiversity loss.

Recommendations

Successful and rapid development and deployment of cultivated meat will require contributions across stakeholder groups — from the greater public to scientists, entrepreneurs, investors, governments, and nonprofits. Below is a list of actions that stakeholders can take to realize the many potential benefits of large-scale cultivated meat production.

Policy recommendations: Governments hold many levers for accelerating cultivated meat technology development and deployment.

[12] (https://gfi.org/wp-content/uploads/2021/03/cultured-meat-LCA-TEA-technical.pdf).

1. **Governments should increase public funds for R&D into cultivated meat technology.** Cultivated meat is still in development and whitespace opportunities to address critical knowledge gaps and optimize scale-up processes are abundant.[13] For example, the LCA and TEA highlight that further cell characterization is needed to inform medium composition and scale-up strategy, media recycling and growth factor optimizations are useful ways to lower costs and boost productivity, and sufficiently upscaled perfusion cultivators tailor-made for meat production and harvesting do not yet exist.[14] A growing number of interdisciplinary students and scientists who see the potential in cultivated meat technology and are eager to address these challenging questions simply do not have access to funding opportunities to pursue their ideas. If funding is acquired, access to essential resources such as animal cell lines remains bottlenecked, further hampering progress.[15]

   Since 2005, global governments have only funded approximately $6.5M into open-access cultivated meat research[16] — a tragically deficient amount of dollars compared to the opportunity cultivated meat holds. Governments must double-down on technologies such as cultivated meat that have the ability to address multiple sustainable development goals in one fell swoop. Governments must also be forward-thinking and realize that the benefits from publicly-funded cultivated meat technology development would see compounding returns on investment over decades. For example, cost reduction and scale-up optimizations in cultivated meat are expected to advance other burgeoning industries such as biologics, cellular therapeutics, and regenerative medicine. And access to cultivated meat can lead to the creation of new hybrid food products that familiarize consumer palettes with other alternative proteins, making them more likely to regularly consume those products. Importantly, a sustained injection of public funding provides training for the future workforce that will build the more resilient food system needed for a growing population.

   Thus far, government funding into open-access cultivated meat research has fallen far short of what is needed. But the tides are beginning to turn as confidence in cultivated meat increases. For instance, the Spanish Centre for the Development of Industrial Technology has backed a project proposing lipid modifications to cultivated meat products as a means to reduce colon cancer and dyslipidemia,[17] Belgium's Ministry of Innovation has provided funding for a public-private partnership to commercialize cultivated foie gras,[18] the United States' National

[13] Visit our solutions database for a full breakdown of challenges facing alternative proteins. (https://gfi.org/alternative-protein-solutions/).
[14] (https://gfi.org/wp-content/uploads/2021/03/cultured-meat-LCA-TEA-technical.pdf).
[15] Read about efforts to expand access to cell lines (https://gfi.org/resource/expanding-access-to-cell-lines/).
[16] Funding numbers compiled internally at GFI. Numbers represent an estimated lower bound and do not include funding from nonprofits or government funding for private industry projects.
[17] (https://www.foodnavigator.com/Article/2021/01/20/Spanish-government-invests-5.2-million-in-cultured-meat-project)
[18] (https://kweekvlees.be/news-articles/diervrije-foie-gras-binnenkort-op-ons-kerstmenu/)

Science Foundation awarded an interdisciplinary academic team to work on developing cell lines, low-cost cell culture media, structuring for whole-cut products, and sensory analysis of end products,[19] and the Japanese Science and Technology Agency has earmarked $20M for cultivated meat research. Additionally, the EU, Japan, Israel, and Singapore have all invested undisclosed amounts into cultivated meat companies.

The time is ripe for governments to seize the opportunity and reap the benefits of becoming global leaders in cultivated meat technology.

A spotlight on Singapore

Forward-thinking countries such as Singapore have already taken charge in establishing an ecosystem to support cultivated meat. As a small island nation that imports over 90% of its food, Singapore views cultivated meat research and commercialization as a critical part of achieving its mission to produce 30% of its food locally by 2030 and, in turn, disarming the looming food security threat it faces. To foster an innovative research community, Singapore leverages its Agency for Science, Technology, and Research (A*STAR), a federally-backed suite of research institutes that aligns competitive advantage with national needs. A*STAR has received S$144M to support its "30 by 30" mission and will use these funds to support cultivated meat research with an eye toward industry collaborations and building up the local talent pool.[20,21]

Singapore aims to create a funnel of innovation by increasing access to venture partners, incubating startups interested in the Asian market,[22] integrating with a strong local biopharma, food, and specialty chemicals manufacturing ecosystem, and supporting technology transfer that greases the wheels for spin-offs and licensing agreements. Additional undisclosed government incentives aim to promote partnerships between local industries, talent, and manufacturing infrastructure. Finally, Singapore has been proactive in establishing a favorable regulatory environment for cultivated meat companies (discussed in (4) below).

Any region, but especially those with high food security threats and high per-capita meat consumption (e.g., Hong Kong, Taiwan, United Arab Emirates, Israel) should look to Singapore as a model for their future food strategy and implementation. Efforts taken by Singapore have already begun to pay off (see section (4) below for more), with the small nation already home to five startups involved in cultivated meat as of writing. Importantly, food security can be

[19] (https://gfi.org/blog/nsf-cultivated-meat-grant/)
[20](https://www.channelnewsasia.com/news/singapore/singapore-to-invest-s-144-million-in-research-on-food-security-11386270#:~:text=Singapore%20has%20identified%20key%20areas,own%20nutritional%20needs%20by%202030.)
[21] (https://www.a-star.edu.sg/ibn/research/cultivated-meat-technologies)
[22] (https://vegconomist.com/society/singapore-emerges-as-the-food-tech-ecosystem-of-asia/)

enhanced by the flexibility of cultivated meat technology, which permits the production of seafood inland and could increase access to meat products in regions with limited access to traditional supply chain or cold chain infrastructure.[23]

2. **Governments should incorporate cultivated meat into their climate change policies and other sustainability policy strategies.** Producing meat through cultivation will help governments achieve net-zero pledges more easily by reducing agricultural emissions associated with conventional meat and poultry production beyond what is possible with interventions in the conventional meat industry (e.g., using feed additives to reduce methane emissions). The LCA shows that if the cultivated meat industry were to rely on sustainable energy versus a business-as-usual energy scenario without additional policy change, then the cumulative environmental impacts of cultivated meat production and its carbon would decrease by approximately 80% and 60%, respectively. But a similarly large benefit is not achievable through decarbonization of conventional animal agriculture. This is because the majority of the climate impact of cultivated meat is concentrated in energy use at the production facility, whereas the climate impacts of conventional animal agriculture are spread across methane and nitrous oxide emissions, land-use change, as well as energy use for the farm, feed, and slaughterhouse facilities.[24]

   Decarbonizing the energy grid in line with Paris Agreement objectives without making changes to how we produce meat would leave a growing percentage of the global carbon budget for limiting warming to 1.5ºC attributable to animal agriculture. Estimates suggest that in business-as-usual scenarios depicting animal agriculture growth as meeting an increasing global meat demand, it could account for up to 80% of the remaining annual carbon budget by 2050.[25] Thus, **governments committed to achieving net-zero emissions through decarbonization of their energy sector can achieve a greater rate of emissions reduction if they also increasingly replace their meat sourcing or production with cultivated meat** (or other alternative proteins)**.** Governments will also see a significantly greater absolute reduction in emissions by switching their meat production to cultivated meat or other alternative proteins such as plant-based meats. Put simply, a transition to cultivated meat aligns with shared global incentives to reduce carbon emissions as fast as possible (alignment in other areas of global need is discussed in “Additional benefits of cultivated meat” below).

[23] Newton, 2021.

[24] According to the FAO, fossil fuel consumption across the conventional livestock supply chain only accounts for ~20% of emissions. (http://www.fao.org/3/i3437e/i3437e.pdf, page xii).

[25] GRAIN: Emissions Impossible, 2018. (https://www.grain.org/article/entries/5976-emissions-impossible-how-big-meat-and-dairy-are-heating-up-the-planet)

Carbon opportunity cost of land use

Another critical area of focus for governments to achieve emissions reductions is related to the carbon opportunity cost of land use. Conventional animal agriculture is the number one cause of global deforestation and biodiversity loss.[26] Between 2001-2015, an estimated 45.1 million hectares (Mha) of forest — an area larger than Paraguay — was converted into cattle pasture. This accounted for 36% of all agriculture-linked tree cover loss worldwide.[27] Another 8.2 Mha was deforested for soy production in South America, where an estimated 80% goes to animal feed, often for export or to feed cattle that are then exported.[28,29,30] This means that many regions (often wealthier) effectively externalize the impacts of their high meat consumption onto other countries, piling climate equity issues on top of emissions related to land-use-change and biodiversity loss in precious rainforests.

Mitigating this loss of land and rewilding it to sequester additional carbon or repurposing it for renewable energy and human food production offers one of the largest long-term levers for slowing climate change and its impacts. The LCA shows that cultivated meat is approximately 3.5x to 16x more efficient than conventional meat production (Table 2). Consequently, cultivated meat reduces land use by 81-95% compared to conventional beef, 72% compared to pork, and 63% compared to chicken (Table 1). In the LCA, this carbon opportunity is not accounted for. **If cultivated meat is substituted in diets and included in governmental climate mitigation strategies that effectively capitalize on the carbon opportunity of land use, then cultivated meat's climate benefits will become significantly greater.**[31]

To highlight this opportunity, a study by Hayek *et al*. found that shifts to primarily plant-based diets by 2050 could sequester an equivalent of 99-163% of the carbon emissions budget for limiting warming to 1.5ºC by implementing changes in global food production and sequestering carbon via ecosystem restoration.[32] With a land footprint identical to tofu production, a switch to cultivated meat likely offers a similar level of opportunity. **The extraordinary potential to sequester large amounts of carbon through changes in land use are therefore not limited**

[26] Machovina, 2015; Dudley, 2017.

[27] World Resources Institute: Deforestation linked to agriculture (https://research.wri.org/gfr/forest-extent-indicators/deforestation-agriculture).

[28] *Ibid*

[29] Approximately 80% of soybeans grown in the Amazon are used in animal feed (https://globalforestatlas.yale.edu/amazon/land-use/soy).

[30] Approximately 11.3 Mha of forest was lost due to importation of animal meat and animal feed crops into the EU from 1990-2014 (Fuchs, 2020).

[31] "Carbon farming" methods such as reduced tillage, planting of cover crops, and applying fertilizers rich in carbon offer additional possibilities to sequester carbon (https://northsearegion.eu/carbon-farming/what-is-carbon-farming/).

[32] The range of 99-163% represents scenarios where consumers shift to a global 70% reduction in meat consumption from business-as-usual scenarios (99% figure) to a fully vegan diet with no animal-sourced foods (163% figure). This is consistent with a 66% chance of limiting warming to 1.5ºC. (Hayek, 2020).

to grand shifts toward plant-based diets — consumers could still eat meat if it is produced in a different way.[33]

Meat Type	Feed Conversion Ratio (kg in per kg out)
Cultivated meat	0.8*
Beef (beef cattle)	5.7**
Beef (dairy cattle)	12.7**
Pork	4.6
Chicken	2.8

Table 2. Reproduced from Table 6 in the LCA report. *The feed conversion ratio is < 1 because of the difference in water content between inputs and outputs. **Does not include human inedible grasses in the calculation.

Putting all options on the table may increase the likelihood of large-scale consumer shifts toward more sustainable foods, which has historically been difficult to achieve by suggestion alone. Future studies should aim to quantify carbon opportunity costs in lands and soils following consumer switches to diets with varying percentages of cultivated meat and other alternative proteins. Analyses related to soil desiccation due to groundwater loss are also recommended.[34] Quantification of the add-on effects related to a decreased animal agriculture footprint on land such as reduced eutrophication, pesticide usage, and limiting the rates of deforestation and biodiversity loss would also be valuable to examine.

3. **Governments should provide incentives to attract new infrastructure projects and provide mechanisms to finance them. Incentives can also be used to accelerate consumer adoption of cultivated meat and limit negative externalities of conventional meat production.** One key aspect of becoming a global leader in cultivated meat production is to attract new infrastructure projects that will provide their populations access to cultivated meat and new job opportunities (discussed in (5) below). The facility modeled in the TEA has expected capital costs of approximately $450M USD (-20% to +40%). To meet just 0.3% of global meat production, 100 similarly-sized facilities would need to be constructed.[35] This

[33] In the meantime, scientific consensus has emerged, which recommends a dramatic decrease in global animal meat consumption to meet climate goals. (Springmann, 2018; Clark, 2020; EAT Lancet Commission Report: https://eatforum.org/content/uploads/2019/07/EAT-Lancet_Commission_Summary_Report.pdf).
[34] Blue water (found in surface and groundwater reservoirs) use was quantified in the LCA. When using sustainable energy, cultivated meat uses up to 78% less blue water than beef production. See Figure 15 of the LCA report for further details.
[35] It should be expected that cultivated meat manufacturers will pursue both scale-up (i.e., beyond the size of the facility used in the model) and scale-out strategies (i.e., making copies of smaller or similarly-sized facilities as the one used in the

underscores the need for a lot of new infrastructure (including an assessment for refurbishing potential) and mechanisms for financing those projects.

Looking to other industries in cleantech or alternative proteins can provide valuable insights into how governments — at international, national, and sub-national levels — can support cultivated meat. In the US, Nevada was chosen as the manufacturing site for Tesla's gigafactory due to years of exemptions granted on sales and property taxes on top of other tax credits, which over the next 20 years could total $1.3B.[36] A project of this scope is far from happening in cultivated meat, but governments and economists can begin mapping the costs, benefits, and risks of similar tax incentive-driven deals for cultivated meat facilities as the industry matures. The allure of creating new manufacturing jobs — especially for regions that have seen losses to globalization — is likely to be enough to incentivize the pursuit of similar deal structures.

Governments can also provide debt financing for large infrastructure projects, and more mature segments of the alternative protein industry are already beginning to see this play out. The appeal of the rapidly expanding plant-based meat industry has begun to incentivize governments to provide federal debt financing for new infrastructure that boosts their local economies, helps meet sustainability goals, and can enhance traceability of ingredients or products, which is increasingly being demanded by consumers. For instance, Canada's climate is ideal for growing legumes such as peas that are heavily used in plant-based meat production. The government has stepped in to finance new facilities[37] and provide funding for R&D and other commercial activities related to the growth and processing of legumes and other crops.[38] As the cultivated meat industry matures, it should encourage governments to step up to provide similar support.

Other forms of consumer- and business-centric incentives can accelerate the pace of adoption of a new technology, which is often competitively disadvantaged by incentive structures that favor the incumbent industry. For example, Norway is the runaway leader in electric vehicle adoption due to an accumulation of incentives that began to be implemented over 20 years ago.[39] Incentives range from decreased annual registration taxes, free parking, access to bus lanes, 0% import tax, and 0% VAT taxes on electric vehicle purchases (compared to 25% tax on fossil fuel cars), which led to price parity of electric vehicles being achieved significantly

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model) depending on their business model and ultimate goals. Success of pilot-scale operations over the next two years will be crucial in dictating near-term strategies for planned increases in scale.

[36](https://www.theverge.com/2016/2/8/10937076/tesla-gigafactory-battery-factory-nevada-tax-deal-elon-musk)

[37] The government of Canada has recently provided financing of $100M for a new pea and canola protein processing facility. (https://www.newswire.ca/news-releases/boosting-canada-s-reputation-as-a-global-leader-in-plant-proteins-865970517.html).

[38] Canada's Protein Industries Supercluster (https://www.ic.gc.ca/eic/site/093.nsf/eng/00012.html).

[39] For a full timeline, see (https://wallbox.com/en_us/how-norway-became-a-global-ev-leader).

earlier than other regions. Of course, not all car-buying incentives align with meat production and purchasing, but import- and export-based trade incentives (e.g., for end products or raw materials used as feed in cell culture media) as well as incentives for restaurants, food assistance programs, and large food suppliers (e.g., school systems, hospitals, and militaries) to replace conventional meat with cultivated meat or other alternative proteins make sense.

4. **Governments should create transparent and robust regulatory frameworks that foster innovation in the cultivated meat industry.** Governments across the globe that are weighing cultivated meat technology must strike the careful balance of establishing regulatory frameworks that ensure consumer safety and product quality while not imposing unnecessary red tape. Currently, the lack of detailed regulatory guidance in many countries poses a challenge for cultivated meat manufacturers getting to market as well as for suppliers of inputs and equipment in meeting industry specifications.

   In December of 2020, the Singapore Food Agency's proactive engagement with industry and science-based regulatory approach led to the first approved sale of a cultivated meat product — a cultivated chicken bite product manufactured by US-based Eat Just, Inc. Shortly thereafter, the first consumer sale was made in a restaurant setting.[40] For the manufacturing of its product, Eat Just has partnered with Singapore's local Food Innovation and Resource Center.[41] With local infrastructure and regulations already in place, Singapore is poised to be at the top of the list for other cultivated meat manufacturers to debut their products. A clear and robust regulatory environment and flourishing R&D environment coupled with local infrastructure and talent make it likely that Singapore will remain a hub of further cultivated meat innovation for years to come.

   At the same time, pressure on regulators in other regions is mounting.[42] The Singaporean regulatory process took two years to complete; but with a framework in place, additional approvals are expected on shorter timelines — and shorter timelines are important to a nascent industry primarily backed by venture capital. Countries that have not yet considered how cultivated meat fits into their existing regulatory frameworks or regions where approval processes are expected to be long-lasting could see slower entry of cultivated meat into their markets.

[40](https://gfi.org/blog/cultivated-meat-singapore/)

[41](https://www.bloomberg.com/news/articles/2020-12-02/singapore-becomes-first-country-to-approve-lab-created-meat)

[42] As of writing, GFI is aware of Canada, Australia/New Zealand, the UK, and the EU as all currently having an applicable regulatory framework relevant to cultivated meat, the US, Japan, and Israel with an expressed interest in cultivated meat with regulatory updates expected soon, and India, Brazil, and China as monitoring global progress with an eye to creating a path to market.

While the Singapore Food Agency has released guidance for cultivated meat manufacturers,[43] the public information is not yet comprehensive and to our knowledge, most conversations between regulators and manufacturers take place on a case-by-case basis. **Governments, regulatory authorities, and cultivated meat manufacturers should openly release any comprehensive regulatory frameworks, requirements, or datasets (when applicable) they have established or generated.** Increased transparency serves multiple purposes: it can increase consumer trust whilst informing cultivated meat manufacturers and others along the supply chain (including facility construction firms and suppliers of cell culture media, scaffolds, cultivators, and other equipment) of the unique requirements of cultivated meat manufacturing, which are expected to lie at the nexus of established food and biopharma regulatory guidances.

Nonprofits might also have a role to play in the regulation of cultivated meat. For instance, nonprofits may seek to develop recommendations for best practices related to cultivated meat manufacturing and ensuring consumer food safety.[44] They may organize stakeholders to align regulatory consensus across different regions such that cultivated meat manufacturers are not faced with a completely new set of requirements when entering a new market. And nonprofits could serve a role in coordinating the development of industry standards that become implemented throughout the cultivated meat industry.

5. **Governments should support cultivated meat as a means to create new high-paying job opportunities in both rural and urban areas.** Cultivated meat permits the decoupling of meat production from primarily rural areas, and production in urban areas may come with several socioeconomic implications. The analogy between rural and urban cultivated meat facilities as being similar to beer brewing is likely to hold, with smaller-scale “microbrewery” facilities (less than the size in the TEA) located primarily in urban areas and large- to mega-scale facilities (the same size or larger than in the TEA) located in more rural areas. The economics along the scaling spectrum need to be further studied, but it is likely that facilities located in both rural and urban areas will exist in the future.

   As described in the technical summary, cultivated meat manufacturers may be motivated to construct facilities in regions that lower the costs and environmental footprint of cultivated meat production by, for example, locating in regions with readily-accessible renewable energy.[45] Co-locating a cultivated meat production facility in a region with access to raw

[43] Singapore Food Agency guidance (https://www.sfa.gov.sg/docs/default-source/food-import-and-export/Requirements-on-safety-assessment-of-novel-foods_23-Nov-2020.pdf)
[44] New Harvest, a nonprofit focused on advancing cellular agriculture, has funded a project that outlines safety considerations. (Ong, 2021).
[45] See (https://gfi.org/wp-content/uploads/2021/03/cultured-meat-LCA-TEA-technical.pdf).

materials or raw material processing infrastructure (typically in rural areas) could also make sense. However, governments may be motivated to have a say in facilities' locations as a means to provide new job opportunities for rural or underserved communities.

For example, the TEA estimates that a facility of the size modeled in the report would staff ~200 individuals including operators, lab technicians, managers, and maintenance personnel at an average salary of $100,000.[46] Although some jobs in the facility would be highly skilled (particularly R&D technicians and managers), operating equipment, other general floor work, and maintenance would likely be attainable to blue-collar workers that hold similar positions in other food processing facilities. In addition to higher pay, worker conditions are likely to be less hazardous than modern chicken and pig farms and slaughterhouses.[47] Working communities can also benefit from reduced odors, cleaner air, and less polluted waterways because cultivated meat could reduce pollution by 29% to 93% compared to conventional meat production methods (Table 1). Other job opportunities elsewhere in the supply chain such as distribution, manufacturing cultivators, and growing and processing cell culture media input materials[48] can also provide new options for livelihoods in rural and underserved communities, although further economic analyses are needed to assess this.

Governments may construct programs that provide training assistance for transitioning workers into new opportunities within the cultivated meat industry. And nonprofits can educate current meat production workers about how to best mitigate occupational risk as well as students about the skills they would need to be well-positioned for a job in the industry.

As suggested in (1) above, increased government funding of open-access R&D at universities and translating novel research and technology into the commercial sector will be a crucial component to the success of cultivated meat. However, many scientist-entrepreneurs are often forced to move to urban areas with concentrated capital to raise funds and start their businesses. But this trend (which has also been impacted by COVID-19) may change, brought on by the growing opportunity to capitalize on foodtech research performed at predominantly rural, ag-centric universities. For example, Big Idea Ventures, which has funded many cultivated meat and alternative protein companies, recently launched a $125M fund specifically aimed at translating food technology development at agricultural universities into

[46] Assumes 24 hour, 7 days-per-week of operations. With optimized processes, the facility's footprint becomes smaller and the number of full-time employees drops to ~130.
[47] For information on slaughterhouse conditions, see Oxfam America "Lives on the Line." (https://s3.amazonaws.com/oxfam-us/www/static/media/files/Lives_on_the_Line_Full_Report_Final.pdf). For conditions related to modern pig and chicken farming, see Leonard, 2014.
[48] Corn and soy are primary inputs for the cell culture media in the LCA and TEA reports, although other input sources such as algae, yeast, fungi, or other crops are also possible.

the rural communities where they are located.[49] Investors, therefore, can start a positive feedback loop for cultivated meat technology development by bridging the gap between university research and commercialization that leads to new business and job opportunities that elevate both urban and rural communities.

6. **Governments and nonprofits should assist farmers and other workers involved in the animal production supply chain in transitioning toward cultivated meat and other alternative protein technologies.** Governments, nonprofits, and other stakeholders have a critical role to play in ensuring an equitable transition of meat production toward cultivated meat and other alternative proteins, which is likely to take shape primarily over the next two decades.

   Cells, like animals, need to eat and the amino acids, sugars, and other feedstock raw materials used in cell culture media must be grown by participants upstream in the supply chain. While the LCA and TEA assume soy hydrolysate as a primary source of amino acids, there is no clear consensus on what crops or other sources (e.g., algae, fungi, cyanobacteria) may serve best as primary inputs, from the perspectives of cost, sustainability, and meeting the metabolic needs of the diverse cells used in cultivated meat production.[50] These same materials may also be used as scaffolding materials in cultivated meat, as feedstock inputs for fermentation of animal proteins or biomass, or as inputs for plant-based meats. Farmer participation in the cultivated meat raw material supply chain offers but one way to participate in the new meat economy built on alternative protein technologies.

   Nonprofits have already begun to support farmers in transitioning to the burgeoning plant-based meat and dairy industries.[51] Similar concepts have been proposed for cultivated meat production. For example, animal breeders (e.g., of Wagyu beef) could earn royalties from unique cell lines used in production or ready-made technology kits could allow farmers to continue to manufacture meat on their farms at smaller scales. There is uncertainty around the economics of such concepts and further studies are needed to assess the tractability of these and other transition concepts.

   Basic thermodynamics and feed conversion data displayed in Table 2 suggest that there is simply less feed needed for cultivated meat than what is needed to create an equivalent amount of meat through conventional production. But farmers will need incentives to change how they use their land. Governments can fuel the transition of farmers involved in the

[49](https://www.foodnavigator-usa.com/Article/2021/01/29/Big-Idea-Ventures-launches-125m-fund-to-help-fund-food-ag-startups-commercializing-groundbreaking-IP-developed-at-universities)

[50] See (https://gfi.org/wp-content/uploads/2021/03/cultured-meat-LCA-TEA-technical.pdf).

[51] Examples include the Transfarmation (https://thetransfarmationproject.org/) and Refarm'd (https://en.refarmd.com/) projects.

conventional animal agriculture supply chain through tax credits on the generation of positive externalities (e.g., land repurposing for carbon sequestration, decreased air and water pollution, or habitat restoration) and penalties on negative externalities, providing subsidies or debt forgiveness to farmers that grow feed for alternative proteins, or otherwise compensating from transition-state losses.

Finally, agricultural systems are complex and differ by region. Any policy or support structure must be equitable in how it affects actors in the current as well as the future food ecosystem. We encourage researchers to leverage data in the LCA and TEA to inform further region-specific studies to best map the actions and policies needed for a smooth transition to cultivated meat and other alternative proteins.

For further discussion of how alternative proteins may affect farmers, we refer the reader to Newton & Blaustein-Rejto, 2021.[52]

Other nonprofit recommendations

1. **Nonprofits should incorporate the recommendations throughout this report as key pillars of their climate and global health policy objectives.** As the LCA and TEA reports highlight, realizing the lower environmental footprint, competitive costs, and other positive externalities of cultivated meat are best achieved in tandem with decarbonization in the energy sector and elsewhere throughout the industrial supply chain. As discussed below (see "Additional benefits of cultivated meat"), the success of cultivated meat is not limited to improvements in environmental impacts, but can also mitigate key global health issues such as antibiotic resistance and the threat of zoonotic disease. Thus, support of cultivated meat technology aligns with the incentives shared by climate and global health nonprofits and should be incorporated into their objectives.

Other investor recommendations

1. **Impact and strategic investors can leverage their expertise to assist cultivated meat manufacturers in reaching their sustainability goals.** Investors in global cultivated meat companies are skewed toward those aimed at targeting a specific relevant category (e.g., foodtech or cleantech) or accomplishing a certain shared mission (e.g., addressing climate change). Investors and cultivated meat companies alike can use insights from the LCA and TEA to craft strategic plans toward accomplishing shared sustainability goals.

[52] Newton, 2021.

For example, Israel-based Aleph Farms has already pledged net zero emissions by 2025 for its cultivated meat production process, has hired a Head of Sustainability, and has assembled a sustainability advisory board (amongst other actions) to accomplish the goal.[53] **Investor groups with expertise in other areas of cleantech can and should assist cultivated meat companies in executing on sustainability goals.** Additionally, investors could require that a cultivated meat manufacturer raising funds commits to certain sustainability goals prior to investing. This would align all parties on sustainability goals and drive competition amongst cultivated meat manufacturers toward achieving them.

Additional benefits of cultivated meat

Key stakeholders have many additional reasons for backing cultivated meat. A narrow focus on carbon emissions is reductionist[54] and fails to capture the add-on effects of a transition to cultivated meat. The LCA and TEA studies increase confidence in cost-competitive, large-scale cultivated meat production with reduced climate impacts being achievable by the end of the decade. Although outside of the scope of these two reports, cultivated meat has the potential to address other large global challenges related to human, animal, and planetary health if it were to take significant market share away from conventional meat and seafood production. **We encourage stakeholders to seriously examine cultivated meat adoption as a means to mitigate these issues.** Additional analyses of value, which may also be region-specific, are listed below.

1. **Effects on oceans and marine habitats.** With over 90% of wild fisheries classified as overfished or harvested at maximal capacity and the additional negative externalities associated with the fishing (e.g., human rights violations, bycatch, overfishing, plastic pollution) and aquaculture (e.g., antibiotic use, coastal habitat destruction) industries, the adoption of cultivated seafood can help take the burden off of the oceans and allow them to recover.[55] LCAs for wild-caught and aquacultured seafood can be performed and compared to cultivated seafood to better understand its potential environmental and supply chain benefits. Further analyses are recommended to understand how adoption of cultivated seafood may mitigate other aforementioned externalities.[56]
2. **Effects on biodiversity.** The expansion of conventional animal agriculture externalizes numerous impacts that influence biodiversity loss and accelerate extinction rates. These externalities include the massive extents of cleared land, especially in South and Central American rainforests, for cattle and soybean production used in animal feed,[57] manure and

[53](https://www.prnewswire.com/news-releases/aleph-farms-going-carbon-neutral-by-2025-301045130.html#:~:text=REHOVOT%2C%20Israel%2C%20April%2022%2C,entire%20supply%20chain%20by%202030).
[54] See (https://newrepublic.com/article/159153/climate-change-dismiss-meat-emissions-wrong).
[55] See (https://gfi.org/resource/an-ocean-of-opportunity/).
[56] Halpern, 2021.
[57] Pendrill, 2019. World Resources Institute: Deforestation linked to agriculture (https://research.wri.org/gfr/forest-extent-indicators/deforestation-agriculture).

nutrient runoff that has led to over 500 dead-zones of oxygen-depleted waters worldwide,[58] and increased use of pesticides, fungicides, and herbicides. Business-as-usual scenarios for animal agricultural expansion suggest that nearly 88% of terrestrial vertebrates would lose habitat to agricultural expansion by 2050.[59] Insights from the LCA suggest that all of these impacts would be dramatically decreased with adoption of cultivated meat and future analyses may aim to quantify the effects cultivated meat could have on rates of biodiversity loss.

3. **Effects of decreased microbiological counts on final products.** Due to the nature of its manufacturing process, cultivated meat is expected to have minimal bacteria present on the final product.[60] Additionally, many of the most common causes of foodborne illness related to animal slaughter (e.g., *E. coli, Campylobacteria, Salmonella)* are not expected to be present in cultivated meat. Thus, cultivated meat should significantly reduce the incidence rates of foodborne illness caused by meat and seafood consumption and could reduce meat and seafood waste due to bacteria-mediated spoilage.
4. **Effects of meat and seafood production without antibiotics.** Antibiotics are not anticipated to be used in cultivated meat production[61] and a switch to cultivated meat could thus save on the over 200,000 tons of annual antibiotic use expected to be attributed to animal agriculture by the year 2030.[62] The potential human health, terrestrial and marine ecotoxicity, and economic benefits are massive in light of the growing prevalence of antibiotic resistance, poor incentive environment for the discovery of new antibiotic drugs in biopharma, and poor disposal practices of hazardous antibiotic mycelial residues.[63]
5. **Mitigation of zoonotic disease and global pandemic risk.** COVID-19 has demonstrated that the human population is still vulnerable to devastating pandemics. Approximately 75% of new and emerging infectious diseases are zoonotic in origin,[64] and the vast majority of these originate in livestock or other domesticated and intensively farmed animals.[65] The consequences of a significant shift to cultivated meat production should be examined seriously as a means to mitigate the risk of zoonotic disease originating from intensively farmed animals.

These suggestions represent a non-exhaustive list of the potential add-on effects of a transition to cultivated meat. We encourage cross-disciplinary teams within governments, academia, industry, and nonprofits to explore the implications of future scenarios where cultivated meat is a mature industry with accelerating market share.

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[58] Dudley, 2017.
[59] Willams, 2020.
[60] Rigorous data to support these claims are currently limited. Additional data is anticipated to become available upon the regulatory approval of additional cultivated meat products or ongoing academic research.
[61] The first approved CM product in Singapore is produced without antibiotics (https://goodmeat.co/).
[62] Van Boeckel, 2017.
[63] Chen, 2017.
[64] (https://www.who.int/neglected_diseases/diseases/zoonoses/en/).
[65] COVID-19 is zoonotic in origin but is not directly attributable to intensively farmed animals.

Conclusion

The LCA and TEA reports are the first ever reports in the cultivated meat literature to be informed by industry. With data and insights from more than 15 different companies, we believe these studies point to the power of collaboration and paint the most complete picture of the costs and environmental impacts of large-scale cultivated meat production to date. To accelerate the development, deployment, and adoption of cultivated meat, key stakeholder groups must invest more resources into cultivated meat technology, foster innovative environments, and enact policies that nurture growth while permitting an equitable shift toward cultivated meat and other alternative proteins. The LCA and TEA suggest that cultivated meat can stand alone as a technology platform and, together with other alternative proteins, become a sustainable and cost-effective means of providing protein to a growing population. Success of cultivated meat in the marketplace holds tremendous potential to offset the negative externalities of conventional meat and seafood production while aligning with other global initiatives to improve human, animal, and planetary health. This summary's recommendations represent a starting point for thinking more deeply about strategic actions and implementation of smart policies by stakeholder groups that will advance cultivated meat. Refined and region-specific analyses built on the foundation of the LCA and TEA reports will also be crucial in establishing the best path forward.

References

1. Chen, Wei, Yong Geng, Jinglan Hong, Harn Wei Kua, Changqing Xu, and Nan Yu. 2017. "Life Cycle Assessment of Antibiotic Mycelial Residues Management in China." *Renewable and Sustainable Energy Reviews* 79 (November): 830–38.

2. Clark, Michael A., Nina G. G. Domingo, Kimberly Colgan, Sumil K. Thakrar, David Tilman, John Lynch, Inês L. Azevedo, and Jason D. Hill. 2020. "Global Food System Emissions Could Preclude Achieving the 1.5° and 2°C Climate Change Targets." *Science* 370 (6517): 705–8.

3. "Deforestation Linked to Agriculture." n.d. Accessed February 17, 2021. https://research.wri.org/gfr/forest-extent-indicators/deforestation-agriculture.

4. Dudley, Nigel, and Sasha Alexander. 2017. "Agriculture and Biodiversity: A Review." *Biodiversity* 18 (2-3): 45–49.

5. Fuchs, Richard, Calum Brown, and Mark Rounsevell. 2020. "Europe's Green Deal Offshores Environmental Damage to Other Nations." *Nature* 586 (7831): 671–73.

6. Gerber, PJ., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Djikman, J., Falcucci, A., & Tempio, G. 2013. "Tackling Climate Change through Livestock: A Global Assessment of Emissions and Mitigation Opportunities." Food and Agriculture Organization of the United Nations. http://www.fao.org/3/i3437e/i3437e.pdf.

7. Goedkoop, M. 2009. "ReCiPe 2008: A Life Cycle Impact Assessment Method Which Comprises Harmonised Category Indicators at the Midpoint and Endpoint Level." https://www.leidenuniv.nl/cml/ssp/publications/recipe_characterisation.pdf.

8. Halpern, Benjamin S., Jason Maier, Heather J. Lahr, Gordon Blasco, Christopher Costello, Richard S. Cottrell, Olivier Deschenes, et al. 2021. "The Long and Narrow Path for Novel Cell-based Seafood to Reduce Fishing Pressure for Marine Ecosystem Recovery." *Fish and Fisheries* , no. faf.12541 (February). https://doi.org/10.1111/faf.12541.

9. Hayek, Matthew N., Helen Harwatt, William J. Ripple, and Nathaniel D. Mueller. 2020. "The Carbon Opportunity Cost of Animal-Sourced Food Production on Land." *Nature Sustainability*, September. https://doi.org/10.1038/s41893-020-00603-4.

10. Leonard, Christopher. 2014. *The Meat Racket: The Secret Takeover of America's Food Business*. Simon & Schuster.

11. Machovina, Brian, Kenneth J. Feeley, and William J. Ripple. 2015. "Biodiversity Conservation: The Key Is Reducing Meat Consumption." *The Science of the Total Environment* 536 (December): 419–31.

12. Newton, Peter, and Daniel Blaustein-Rejto. 2021. "Social and Economic Opportunities and

Challenges of Plant-Based and Cultured Meat for Rural Producers in the US." *Frontiers in Sustainable Food Systems* 5: 10.

13. Ong, Kimberly J., Jeremiah Johnston, Isha Datar, Vincent Sewalt, Dwayne Holmes, and Jo Anne Shatkin. 2021. "Food Safety Considerations and Research Priorities for the Cultured Meat and Seafood Industry." Authorea, Inc. https://doi.org/10.22541/au.161246496.61092571/v1.

14. Pendrill, Florence, U. Martin Persson, Javier Godar, Thomas Kastner, Daniel Moran, Sarah Schmidt, and Richard Wood. 2019. "Agricultural and Forestry Trade Drives Large Share of Tropical Deforestation Emissions." *Global Environmental Change: Human and Policy Dimensions* 56 (May): 1–10.

15. Poore, J., and T. Nemecek. 2018. "Reducing Food's Environmental Impacts through Producers and Consumers." *Science* 360 (6392): 987–92.

16. Qualman, Darrin. 2018. "Emissions Impossible: How Big Meat and Dairy Are Heating up the Planet." GRAIN and Institute for Agriculture and Trade Policy. https://www.grain.org/article/entries/5976-emissions-impossible-how-big-meat-and-dairy-are-heating-up-the-planet.

17. "Soy Agriculture in the Amazon Basin." n.d. Accessed February 17, 2021. https://globalforestatlas.yale.edu/amazon/land-use/soy.

18. Springmann, Marco, Michael Clark, Daniel Mason-Damp x. Croz, Keith Wiebe, Benjamin Leon Bodirsky, Luis Lassaletta, Wim Vries, et al. 2018. "Options for Keeping the Food System within Environmental Limits." *Nature*, October, 1–24.

19. Van Boeckel, Thomas P., Emma E. Glennon, Dora Chen, Marius Gilbert, Timothy P. Robinson, Bryan T. Grenfell, Simon A. Levin, Sebastian Bonhoeffer, and Ramanan Laxminarayan. 2017. "Reducing Antimicrobial Use in Food Animals." *Science* 357 (6358): 1350–52.

20. Willett, Walter. 2020. "Healthy Diets from Sustainable Food Systems." EAT Lancet Commission. https://eatforum.org/content/uploads/2019/07/EAT-Lancet_Commission_Summary_Report.pdf.

21. Williams, David R., Michael Clark, Graeme M. Buchanan, G. Francesco Ficetola, Carlo Rondinini, and David Tilman. 2020. "Proactive Conservation to Prevent Habitat Losses to Agricultural Expansion." *Nature Sustainability*, December, 1–9.

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Acknowledgments

The Good Food Institute would like to thank the research team at CE Delft — especially Ingrid Odegard, Pelle Sinke, and Robert Vergeer for managing and assembling the LCA and TEA reports. GFI would like to thank GAIA for co-commissioning the LCA report. GFI is immensely grateful to all of the data providers and knowledge collaborators for making this work possible.

The Good Food Institute is a 501(c)(3) nonprofit organization. Our family of donors powers our progress toward a world where alternative proteins are no longer alternative.

About GFI

The Good Food Institute (GFI) is a 501(c)(3) nonprofit working internationally to make alternative proteins like plant-based and cultivated meat delicious, affordable, and accessible. GFI advances open-access research, mobilizes resources and talent, and empowers partners across the food system to create a sustainable, secure, and just protein supply.