FEASTS
Fostering European Cellular Agriculture for Sustainable Transition Solutions

Strategic road map for the cultured meat and seafood sector

Deliverable 2.3

Author (s)

Name	Organization
Dwayne Holmes	New Harvest - Netherlands

Reviewed by

Name	Organization
Marius Henkel & Katharina Brenner	TUM
Jordi Morales & Elena Bittner	Cultimate Foods
Megumi Yoshitomi	JACA
Frederico Ferreira & Gonçalo Fernando	IST-ID

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Note: This report was written for submission at month 18, which is the midpoint of the project. This means that much of the work being done in different work packages (WPs) has not been completed and/or made ready for dissemination. Information used from the previous generic road mapping exercise (milestone M4), including sections related to specific work being done in FEASTS, has not changed, outside of WP3 that has more detailed data about the technologies. This report builds upon milestone 4 by adding sections that provide: 1) a high-level gap analysis, 2) a strategic road map based on that analysis, and 3) an overview of opportunities for stakeholders to bridge the critical gaps that the sector faces at the moment (including examples of existing actions). While deliverable 2.3 will remain as it is submitted, updates of the strategic plan resulting from FEASTS activities, additional findings generated from all WPs, and sector evolution will be integrated on D2.6 FEASTS White paper harnessing R&D to further societal goals, as well as on D7.4 Policy recommendations and National action plans and 7.6 Exploitation strategy and funding watch.

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List of Acronyms and Abbreviations

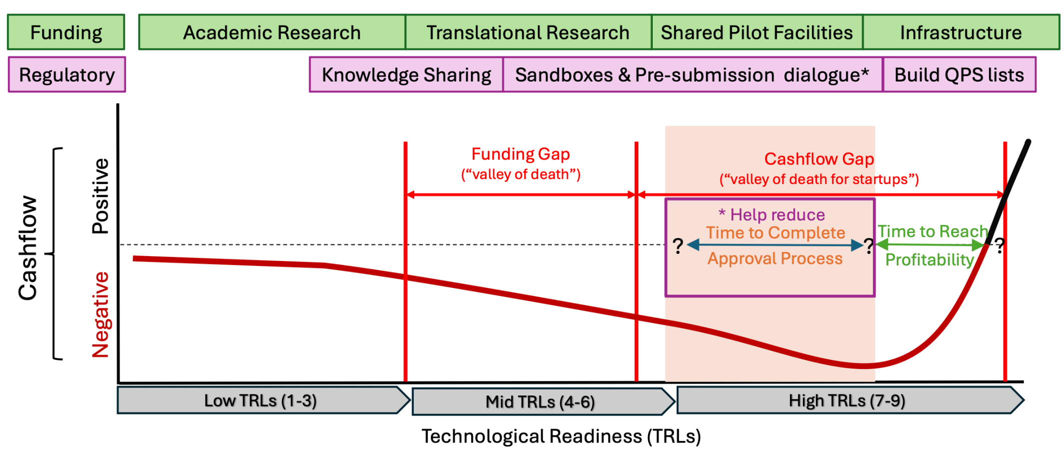
AI - Artificial Intelligence
CA - cellular agriculture (sometimes shortened to "cell ag")
CAN - Cellular Agriculture Netherlands
CAPE - Cellular Agriculture Prairies Ecosystem (Canada)
CARMA - Cellular Agriculture Manufacturing Hub (UK)
CM - cultured meat (aka cultivated meat, cell-based meat, etc.)
CMSI - cultured meat safety initiative
CSF - cultured seafood (aka cultivated seafood, cell-based seafood, etc.)
EC - European Commission
EFSA - European Food Safety Authority
EU - European Union
FAO - Food and Agriculture Organization (a department of the United Nations)
FSA - Food Standards Agency (UK)
GFI - Good Food Institute
JACA - Japanese Association for Cellular Agriculture
KPI - key performance indicator
LCA - life cycle analysis
NGO - non-governmental organization
TEA - techno-economic assessment
TRL - technology readiness level
UK - United Kingdom
UN - United Nations
US - United States of America
WHO - World Health Organization
WP - work package (within FEASTS project)

Executive Summary

The following report presents a high-level gap analysis for the state of cultured meat and seafood (CM/CSF) technologies, which combined with current trends in private investment and support from the public provides a picture of the sector as it stands today. Based on this, a strategic road map is offered, giving examples of how various stakeholders can and are working to achieve desired goals. This report takes a position that continued focus on longer-term needs of a commercial industry, particularly when reliant on aspirational beliefs, needs to be replaced with feasible short/medium-term actions, capable of moving the sector forward in a realistic development pathway. In addition to addressing the needs of private developers, a focus on knowledge creation and technology development with accurate and near-to-mid-term objectives is a priority to build confidence and nurture overall sector growth.

Next steps/goals on this strategic road map are identified as:
1. Establish the technology[1],
2. Improve data sharing and retention,
3. Establish mechanisms to understand impacts,
4. Promote standards of practice,
5. Develop feasible implementation plans that include resource requirements[2],
6. Establish better comms and approaches[3].

Opportunities for governments to support the field is summarized in the following figure.



Top-line opportunities for government action to impact CM/CSF sector. Opportunities categorized by funding and regulatory activity, and ordered relative to stages of development. Actions reducing time to complete the approval process can shorten the cashflow gap and improve survival of startups (from Fig 8 in report).

1 Forecast actions include critical work at low technology readiness levels (TRLs) in addition to scale-up.
2 Such plans should include outreach to other stakeholders who may be affected by adoption.
3 Communications focused on attracting investors, may not be suitable for policymakers and the public at large, who are also critical for its success.

1. Introduction

Cultured meat and seafood (CM/CSF) technologies are championed for the potential benefits they offer compared to our current, often intensive, methods of animal agriculture. By growing animal cells and tissue under culture conditions, the CM/CSF sector may avoid the negative environmental, health, and ethical aspects of raising, slaughtering and processing whole animals. The relevance of this increases when considering the projected growth in demand for animal-derived products in the coming decades (FAO, 2018; Systemiq, 2024) (Fig1).

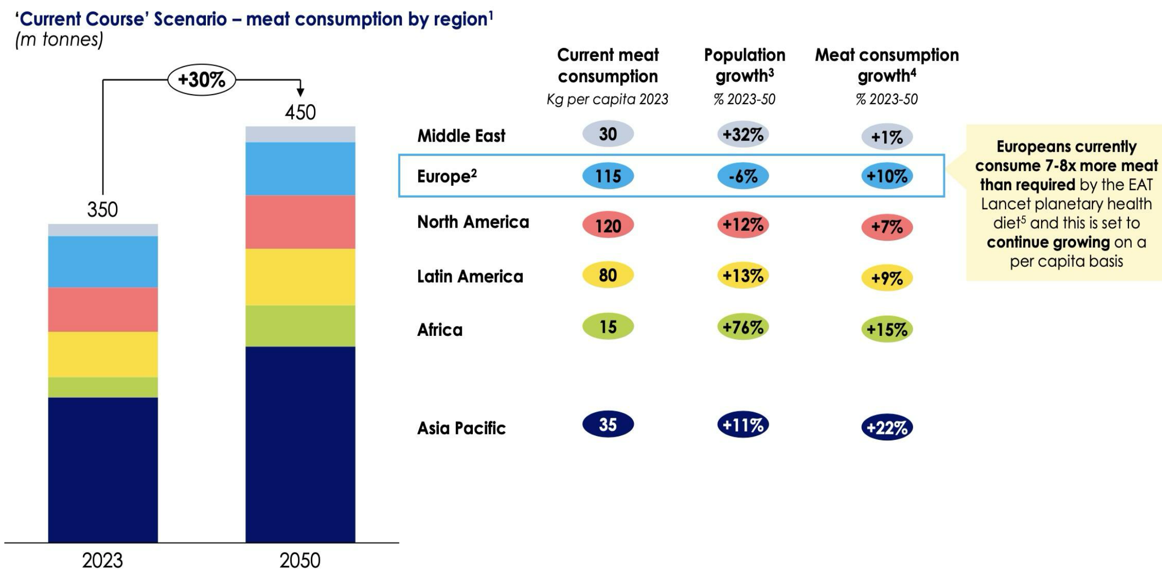


Figure 1. Projected levels of meat consumption in 2050, by region. Sources & Notes: 1. Systemiq analysis using FAOSTAT 2020 consumption data and Business-As-Usual Scenario growth to 2050; 2. EU and rest of Europe combined; 3. World Bank population data (2023); 4. Based on per capita meat consumption. 5. Eat Lancet (2019) Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. (Systemiq, 2024).

A small number of products have already been granted access to markets outside the European Union (EU) and, as of this writing, two dossiers submitted for approval in the EU. However, emerging CM/CSF technologies are still in early stages of development and thus are unable to provide the targeted benefits; which upon implementation will require adequate assessment. That means the journey to achieving what in this report are designated as "mission" goals for these technologies lies largely ahead of us. This report, along with supporting files, is intended to function as a road mapping tool, documenting what would be required to get from the current state of the CM/CSF sector to achieving its target benefits and so reaching "mission" goals. It builds on an earlier report (FEASTS milestone M4, an internal, road mapping exercise used as a general guide to understand the sector and to document relevant research priorities within FEASTS). More granular information is added and, crucial for this deliverable, a set of proposed strategies for different stakeholder groups to make progress toward the goals in an efficient manner.

Road mapping within this document includes identifying expected milestones, key performance indicators, benchmarks, required infrastructure, and viable areas for pre-competitive research and collaboration. Achieving expected benefits, and avoiding potential adverse impacts, involves not only development of the technology, but also definition of multi-dimensional strategies for implementation of such technologies. This involves socio-economic and ethical dimensions related to their adoption. After all, much of the impacts that the CM/CSF sector can achieve depends on sufficient adoption by society to have large scale effects.

A key challenge to this effort is the absence of a universally applicable approach to CM/CSF production. For each animal species, production step, and type of end product, milestones and benchmarks may vary significantly. Moreover, multiple technologies and methods of implementation may be available for any given product and implemented differently by producers. Given that fact, a singular road map applicable to all technologies and products cannot be produced, nor will a complete catalogue of road maps covering all possible combinations be attempted. Instead, this report is intended to provide a comprehensive overview of the field and to identify key elements that should be considered when developing road maps for any CM/CSF technology. Following from this, the strategic portion will naturally have to be high-level, with flexibility to be "zoomed in" on specific components.

As a deliverable, this report is intended to stand on its own and can act as a snapshot for the sector at its publication. However, at such an early stage of development and with so many moving parts, it is arguably a foundation or source of information for future road maps. It is also intended to be a living document, in spirit if not in fact, which can continue to be developed or used by others after the end of the project.

Note: Sections 2 and 3 provide background information about the CM/CSF sector and a rationale for proposed actions in the strategic road map. **Readers primarily interested in recommended actions for stakeholders may skip directly to section 4, The Strategic Road Map.**

2. Generic Road Map for the CM/CSF sector

By focusing on target benefits, and ignoring all potential variations in technologies or forms of implementation, it is possible to construct a high-level, generic road map for the CM/CSF sector as a whole. It is a bare-boned set of expectations that would likely hold regardless of the exact path followed.

2.1 Common Milestones

Milestones are critical events or achievements that show progress toward a goal is being made. These are the most straightforward way of outlining a “road map” for CM/CSF technologies, and can be divided into classes related to: 1) type of progress: whether technological development or an aspect of its implementation, 2) subject area of development or implementation it addresses, and 3) mission goal being served.

Mission goals may be defined by positive impacts on the environment, health (human or animal), animal welfare, or sustainability. In the latter case, sustainability refers to various aspects beyond environmental impacts that would determine the CM/CSF sector's long-term viability and allow it to become part of a future agricultural system. Fulfilling such mission goals, implies reaching several technological requirements as well as respecting socio-economic and ethical dimensions of how foods would be produced in practice. Namely, implementing strategies for CM/CSF sector growth and adoption of products that avoids or mitigates disruption of people's lives and livelihoods.

Table 1 shows major, generic milestones expected for CM/CSF technologies, with relevant classes identified for each. Note that while milestones do not have to be achieved in the order they appear on the table, and not all may not be relevant for any given CM/CSF pathway, they are presented in a basic order of progression from foundational elements of the technology to its implementation in a way that, by targeting to achieve, eventually reach mission goals.

Table 1. Common Milestones for CM/CSF Technologies

Type of Progress	Subject	Milestone	Mission Goals
Development	Cells	Production cells/lines obtained without animal slaughter	Animal welfare
Development	Cells	Production cells/lines obtained without animal injury	Animal welfare
Development	Cells	Production cells/lines obtained without direct animal contact	Animal welfare
Development	Cells	Production cells/lines with indefinite proliferation	Sustainability
Development	Components	Culture media without fetal bovine serum (FBS)	Animal Welfare
Development	Components	Culture media and support material free from animal-derived products (slaughter/harm)	Animal Welfare
Development	Components	Culture media and support materials free from hazardous compounds	Health
Development	Process	Process capable of producing selected cell/tissue types	Sustainability/ Health
Development	Process	Process capable of producing appropriate cell/tissue composition	Sustainability/ Health
Development	Process	Process capable of upscaling to pilot	Sustainability

Table 1. Common Milestones for CM/CSF Technologies

Type of Progress	Subject	Milestone	Mission Goals
Development	Process	Process capable of scaling (-up or out) beyond pilot	Sustainability
Development	Process	Process capable of commercially relevant volumes/mass (e.g. tons/year)	Sustainability
Development	Process	Process performance equal or better on environmental impact when compared to traditional methods	Environment
Development	Process	Process allows product costs near parity or lower when compared with traditional equivalent	Sustainability
Development	Process	Process allows product costs to be at parity with traditional equivalent	Sustainability
Development	Process	Process allows product costs lower than the traditional equivalent	Sustainability
Development	Product	Product free from slaughter-derived products (preferably also animal harm-free)	Animal Welfare
Development	Product	The product has similar safety compared to its traditional equivalent (e.g. hazard analysis)	Health
Development	Product	Product has improved food safety compared to its traditional equivalent (e.g. hazard analysis)	Health
Development	Product	Product has similar sensory experience to traditional equivalent	Sustainability
Development	Product	Product has similar nutritional content as traditional equivalent	Health
Development	Product	Product has improved nutritional content as traditional equivalent	Health
Development	Product	Product has similar composition as traditional unstructured equivalent	Sustainability
Development	Product	Product has similar composition as traditional structured equivalent	Sustainability
Implementation	Supply	Reliable supply chains to upscale process beyond pilot	Sustainability
Implementation	Supply	Reliable supply chains to upscale the process to commercially relevant volumes/mass	Sustainability
Implementation	Supply	Reliable supply chains that ensure a relatively positive environmental impact	Environment

Table 1. Common Milestones for CM/CSF Technologies

Type of Progress	Subject	Milestone	Mission Goals
Implementation	Regulatory	Acceptance of CM/CSF product(s) to a limited market (e.g. test market, small nation)	Sustainability
Implementation	Regulatory	Acceptance of CM/CSF product(s) to large or multiple markets	Sustainability
Implementation	Regulatory	Acceptance of CM/CSF product(s) to most/all markets	Sustainability
Implementation	Transition	Mechanisms in place to ensure just transition for those in current food value chain	Sustainability
Implementation	Transition	Mechanisms in place to ensure equal access to CM/CSF products (e.g. local, national)	Sustainability
Implementation	Transition	Mechanisms in places to ensure regional food stability and quality	Sustainability
Implementation	Adoption	Adoption reaches 1% of total (worldwide) equivalent animal food product	Sustainability
Implementation	Adoption	Adoption reaches 10% of total (worldwide) equivalent animal food product	Sustainability
Implementation	Adoption	Adoption reaches 25% of total (worldwide) equivalent animal food product	Sustainability
Implementation	Adoption	Adoption reaches 50% of total (worldwide) equivalent animal food product	Sustainability
Implementation	Adoption	Adoption reaches level where improved environmental impacts are evident	Environment
Implementation	Adoption	Adoption reaches level where improved health impacts are evident	Health
Implementation	Adoption	Adoption reaches level where significant improved animal welfare is evident	Animal Welfare

Table 1. Common Milestones for CM/CSF technologies. Milestones are presented in a generally progressive order from foundational technological developments to aspects of its implementation, grouped by the subject the milestone addresses and identifying the mission goal it helps achieve.

2.2 Common Key Performance Indicators

Key performance indicators (KPIs) can be used to assess/measure the current state of the technology, or its implementation. Such metrics can be applied to technological development, both for production stages and to cover non-technological aspects. In this report they are organized into the same categories used for grouping milestones in the previous section, as seen in Table 1.

Benchmarks are defined for quantitative or qualitative assessments for each KPI, relating the furthest extent performance level reached so far and/or expected to be reached with the different stages of development (aka technical readiness levels (TRLs)). As this is a generic list, it will not include benchmarks. However, later sections that deal with more specific technologies (or supporting files for those sections), may include relevant benchmarks for the sector, where they are known, and sufficient public evidence is available.

Table 2 shows common, generic KPIs expected for CM/CSF. Note that while not all of these KPIs may be relevant for any given CM/CSF technology, they will be applicable for most, and are presented in a basic order of progression from foundational elements of the technology to its implementation in a way that, by targeting to achieve, eventually reach mission goals.

Table 2. Common Key Performance Indicators (KPIs) for CM/CSF

Type of Progress	Subject	KPI	Mission Goals
Development	Cells	Cell proliferation capacity (# doublings, stability)	Sustainability
Development	Cells	Cell differentiation capacity (types and maturity)	Sustainability
Development	Components	Amount of animal-derived components in media	Animal Welfare
Development	Components	Amount of animal-derived components in support materials	Animal Welfare
Development	Components	Amount of hazardous compounds in media	Health
Development	Components	Amount of hazardous compounds in support materials	Health
Development	Components	Amount/Cost of raw materials	Sustainability
Development	Components	Amount/Cost of processed materials	Sustainability
Development	Components	Amount/Cost of specialized components	Sustainability
Development	Components	Amount/Cost of equipment	Sustainability
Development	Process	Length of production process	Sustainability
Development	Process	Amount of cell mass produced (e.g. kg/yr)	Sustainability
Development	Process	Amount of product produced (e.g. kg or units/yr)	Sustainability
Development	Process	Cost of cell mass produced (€/kg)	Sustainability

Table 2. Common Key Performance Indicators (KPIs) for CM/CSF

Type of Progress	Subject	KPI	Mission Goals
Development	Process	Cost of cell-derived food product (€/kg)	Sustainability
Development	Process	Medium requirements (e.g. vessel volume/day)	Environment
Development	Process	Energy requirements	Environment
Development	Process	Land requirements	Environment
Development	Process	Water requirements	Environment
Development	Process	Waste generated	Environment
Implementation	Regulatory	Regulatory approval (regions, market size)	Sustainability
Implementation	Adoption	Consumer acceptance	Sustainability
Implementation	Adoption	Market share acquired	Sustainability
Implementation	Adoption	(Reduction in) animals used for food production	Animal Welfare
Implementation	Adoption	(Reduction in) negative environmental impacts	Environment
Implementation	Adoption	(Reduction in) disease in/from animal farming sector	Health
Implementation	Transition	Quantity and quality of work/life for members of traditional food value chain (e.g. retraining)	Sustainability
Implementation	Transition	Quantity and quality of work/life for members of emerging food value/supply chain	Sustainability
Implementation	Transition	Quality of life for communities where CM/CSF adopted (e.g. dietary customs, food access)	Sustainability

Table 2. Common Key Performance Indicators (KPIs) for CM/CSF technologies. KPIs are presented in a generally progressive order from foundational technological developments to aspects of its implementation, grouped by the subject the KPI addresses and identifying the mission goal it helps achieve.

2.3 Common Support Infrastructure

Infrastructure represents both physical and socio-economic support mechanisms that allow for the development and adoption of CM/CSF at scales relevant for achieving maximum potential benefits.

Table 3 shows the common infrastructure expected for CM/CSF. While not all the classifications used so far may be relevant for infrastructure, they will generally borrow from the same list.

Table 3. Common Support Infrastructure for CM/CSF Technologies

Type of Progress	Subject	Infrastructure
Development	Cells	Available cell sources
Development	Cells	Available production cell lines
Development	Components	Raw material producers/distribution
Development	Components	Processed material producers/distribution
Development	Components	Specialized material producers/distribution
Development	Components	Equipment producers/distribution
Development	Process	Talent pool/pipeline (science, engineering, etc.)
Development	Process	R&D facilities
Development	Process	R&D support (e.g. funding)
Development	Process	Scale-up (pilot) facilities
Development	Process	(Open science) Data sharing/networking
Development	Process	Process analytics (suppliers, services)
Development	Product	Safety analytics (suppliers, services)
Development	Process/product	Valorization/standards services
Implementation	Supply	Product distribution networks
Implementation	Adoption	Consumer research
Implementation	Transition	(Re)training for members of traditional food value chain
Implementation	Transition	Support services for members of traditional food value chain
Implementation	Transition	Training for members of emerging CM/CSF value chain
Implementation	Transition	Support services for members of emerging CM/CSF food
Implementation	Transition	Consumer protection services
Implementation	Transition	Support for adoption of CM/CSF products

Table 3. Common Support Infrastructure for CM/CSF technologies. Types of infrastructure are presented in a generally progressive order from foundational technological developments to aspects of its implementation, grouped by the subject the infrastructure would help support.

2.4 Common Areas for Pre-competitive Research & Collaboration

Pre-competitive research and collaboration refer to areas of work that can strengthen the field as a whole, building its foundations up, **before organizations might benefit from acting as competitors**. These areas of work can be identified where:
1) Issues addressed are large, common, and important enough for all to benefit,
2) technologies for which TRLs are low enough that advances would not reasonably hold commercial (or IP) value, and/or
3) where conflicts of interest do not exist.

In such cases, organizations that would otherwise act as competitors will sometimes collaborate to solve key problems. With early and heavy private investment into the CM/CSF sector, this kind of collaborative work has been sorely neglected, arguably leading to slower progress toward increases in TRLs as well as realizing potential benefits.

Table 4 shows common areas for pre-competitive research & collaboration in the CM/CSF sector. Note that while not all may be relevant for the pathway of a given CM/CSF technology, they would hold for the field as a whole and are presented in a basic order of progression from foundational elements of the technology to its implementation in a way that, by targeting to achieve, eventually reach mission goals.

Table 4. Common Areas for Pre-competitive Research & Collaboration for CM/CSF

Type of Progress	Subject	Area	Mission Goals
Development	Cells	Cell sourcing	Animal Welfare
Development	Cells	Cell line development	Sustainability
Development	Components	Culture media development	Sustainability
Development	Components	Culture support material development	Sustainability
Development	Components	Culture equipment development	Sustainability
Development	Process	Culture process development	Sustainability
Development	Process	Upscaling of process	Sustainability
Development	Process	Process analytics	Sustainability
Development	Product	Safety analytics	Health

Table 4. Common Areas for Pre-competitive Research & Collaboration for CM/CSF

Type of Progress	Subject	Area	Mission Goals
Development	Product	Nutritional analytics	Health
Development	Product	Health and Safety of CM/CSF products	Health
Development	Product	Organoleptics (sensory profile) of CM/CSF	Sustainability
Development	Product	Stability of CM/CSF products	Sustainability
Development	Product	Storage, packaging, distribution of CM/CSF	Sustainability
Implementation	Supply	Supply chains	Sustainability
Implementation	Supply	Resource usage	Sustainability
Implementation	Adoption	Waste/circularity	Environment
Implementation	Adoption	Consumer acceptance	Sustainability
Implementation	Regulatory	Regulatory environment/pathways	Sustainability
Implementation	Regulatory	Intellectual Property (rights, uses)	Sustainability
Implementation	Transition	Production/distribution models (centralized, decentralized)	Sustainability
Implementation	Transition	Food security/sovereignty	Sustainability
Implementation	Transition	Educational/research development	Sustainability
Implementation	Transition	Consumer protections	Sustainability
Implementation	Transition	Standards (e.g. technology, business practices)	Sustainability
Implementation	Transition	Integration with the current food value chain/agricultural system	Sustainability

Table 4. Common Areas for Pre-competitive Research & Collaboration for CM/CSF. Areas of potential research and collaboration are presented in a generally progressive order from foundational technological developments to aspects of its implementation, grouped by the subject the pre-competitive effort would address and identifying the mission goal it helps achieve.

2.5 How FEASTS helps build the generic road map

Research conducted within FEASTS can be guided by elements of the generic road map, as they work to generate details at a more granular level. It is intended that this information will in turn help direct or prioritize future research beyond this project.

What follows is a brief description of WPs within the project, and how they may add to the road map. In every case, the diverse number of options that can be mixed and matched regarding process, product, or method of implementation prevents comprehensive coverage. Instead, literature research will provide initial information where there is publicly available data, with workshops, interviews, surveys, or experimental research by FEASTS partners fleshing out this picture, often using specific case studies.

WP3 - Technological development of CM/CSF

WP3 investigates the development of CM/CSF technologies. As such, it helps fill in the road map regarding technological milestones, KPIs, and current benchmarks, allowing different stakeholders, namely decision-makers for public and private investment, to understand where the field stands and where it still requires development.

Since technological information is needed for other WPs, work in WP3 was started early with a recent report (milestone 8) delivering a detailed look at the diversity and complexity of choices available (see FEASTS CM/CSF Process Diagram). The diagram is the most comprehensive picture to date of the range of available options, and helps explain why a singular road map or catalog of road maps would be difficult to produce in a single project. The report also advances five potential products as case studies for business models, and delves into potential product types and supply models in the CM/CSF industry (see FEASTS Milestone 8 report here). In another report, the WP3 team is developing more in-depth and targeted KPIs than those seen in the general roadmap.

WP4 - Socio-economic & ethical aspects of implementation

WP4 investigates socio-economic and ethical aspects of implementing CM/CSF technologies. As such, it will help fill in the road map regarding implementation milestones, KPIs, and current benchmarks, allowing different stakeholders to understand where the field stands concerning its adoption and where further information and/or efforts may be required.

WP5 - Safety & regulatory aspects of implementation

WP5 investigates safety and regulatory aspects of implementing CM/CSF technologies. As such, it will help fill in the road map regarding relevant safety and regulatory milestones, KPIs, and benchmarks, allowing different stakeholders to understand where the field stands concerning its adoption and where further information and/or efforts may be required.

WP6 - Impact Assessment

WP6 investigates methods of analyzing CM/CSF technologies regarding performance and the diverse kinds of impact they might have, as well as conducting such assessments. The most common are LCAs and TEAs, but this will also include social considerations to produce a social life cycle analysis (SLCA). WP6 will help fill in the road map regarding relevant milestones, KPIs, and benchmarks centered on CM/CSF viability and the potential impact it could have on the environment and society. From this, different stakeholders will have a better understanding where the field stands concerning its development and adoption and where further information and/or efforts may be required.

3. Strategic Considerations

The previous section was concerned with describing a road map for the CM/CSF sector, with elements that would likely be found along the way, from the starting point to finish line. Those include descriptions of broad objectives, set out in a plausible order for them to occur. This section provides greater context, by assessing current progress as well as identifying factors that can impact efficient growth of the sector. These form a rationale for recommendations found in the strategic road map.

3.1 Gap Analysis

A gap analysis supports development of a strategy, by providing an understanding of where the CM/CSF sector is and where it would like to end up. Given the diversity and complexity of the technology, it is difficult to produce a robust, accurate, and detailed gap analysis. This task is made harder as most progress has been made by private developers who keep privileged information private in order to protect potential IP. Therefore, while inputs (e.g. funding) and outputs (e.g. number of companies) are available, details on the current extent and nature of development are not, and so using a "black box" model is often required. The result is that the analysis will have to be generic, high level, rather than detailed and granular.

As mentioned in the previous section, work within FEASTS is intended to "open" the black box, when possible, to allow more specific, detailed analyses of where the sector stands. As the project progresses, and certainly by the end, there should be a better understanding along these lines. For now, this report will use recent, comprehensive studies of the sector that involved input from multiple stakeholders.

3.1.1 State of the field

A useful report to understand the current state of the field, a starting point for purposes of building a strategy, was published this year by the Good Food Institute (GFI) (GFI, 2025). Rather than duplicate such information here, it is recommended that the reader access the report for particular aspects of the state of the industry that interest them. What will be useful to quote from is their sober, concluding overview.

"[Quote from GFI report, <u>underlining</u> is from original text, emphasis in **bold** by author] **...**

> ***The cultivated meat sector*** *has achieved significant progress in its first decade, but the industry* ***is almost entirely prerevenue, and a large share of companies remain in the early stages of product research and development****.* ***A handful of products have been sold in limited quantities across three markets,*** *meaning the number of consumers who have ever purchased cultivated meat is somewhere in the <u>thousands.</u> Meanwhile, billions of people worldwide regularly consume conventional meat.*
>
> ***Given the cultivated meat industry's early stage of development, it can be difficult to fully capture activity and advancements in the sector****.* ***Much of the industry's progress occurs through largely unseen developments*** *like process validation, efficiency improvements, and technical breakthroughs. Without full visibility into company-level advancements, factors like public and private funding totals, regulatory approvals, and the formation of research and innovation centers provide other windows into the growing cultivated meat ecosystem.*
>
> *...* ***Private investments in cultivated meat companies declined in 2024, a headwind for an almost entirely prerevenue sector,*** *although additional regulatory approvals could spur new funding opportunities.* ***Those factors, paired with the technical and cost hurdles inherent to any early-stage, high-capital-expenditure sector, present runway challenges for many companies—underscoring the need for multipronged financing strategies from public, private, and philanthropic sources.***

... [end quote]"

This suggests that the current starting point, after ten years of private investment into industry research, is roughly what was described in this report's introduction, "... the journey to achieving what in this report are designated as "mission" goals for [CM/CSF] technologies lies largely ahead of us." Despite approvals and some limited sales, it is safe to treat most of the milestones as viable targets that still need to be achieved. And it is worth pointing out that the sector's current status underlines access to markets is not by itself the "finish line" or even an indicator of the commercial, social, or agricultural viability of the sector. Access to markets will be crucial for CM/CSF technologies to have impact, but a lot can happen on the way to the market or after they get there, which can undercut long-term viability.

3.1.2 Gartner hype cycle and investment cycles

The Gartner hype cycle is a theoretical concept which reflects how interest may wax and wane for technology-based businesses as they move from initial knowledge to long-term productivity. This cycle starts with a jump in public interest based on initial hype that reaches a "peak of expectations", followed by an equal descent as hyperbolic claims are re-examined and people reset expectations downward toward a "trough of disillusionment" before rebounding back up in a "slope of enlightenment" as realistic claims and possibilities are accepted to stabilize in a "plateau of productivity".

In 2023, New Harvest published an estimate of where the CM/CSF sector was in this cycle (Fig 2), placing it at the start of the downward trend in interest after having reached the peak of the hype cycle in late 2021. Whether this is accurate or not, it was based on and so reflects declining interest by investors as early predictions for success were missed, leading to the closing of businesses or changes in business models. This growing disinterest can feed on itself, leading to more failures and so more disinterest, until the sector hits the bottom of the trough. The problem from a strategic standpoint is that if enough interest is lost, the sector can become paralyzed, regardless of the underlying viability of a technology, with no guarantee it will rebound. For those developing the technology, such stagnation can be fatal, as investment, whether public or private, can disappear as excitement nosedives. This is particularly true for businesses that are pre-revenue. Making it from early stages, where there is still much work to be done without an income, to commercial viability, is known as the "valley of death" and, in this case, may well mirror the trough seen in the Gartner hype cycle.

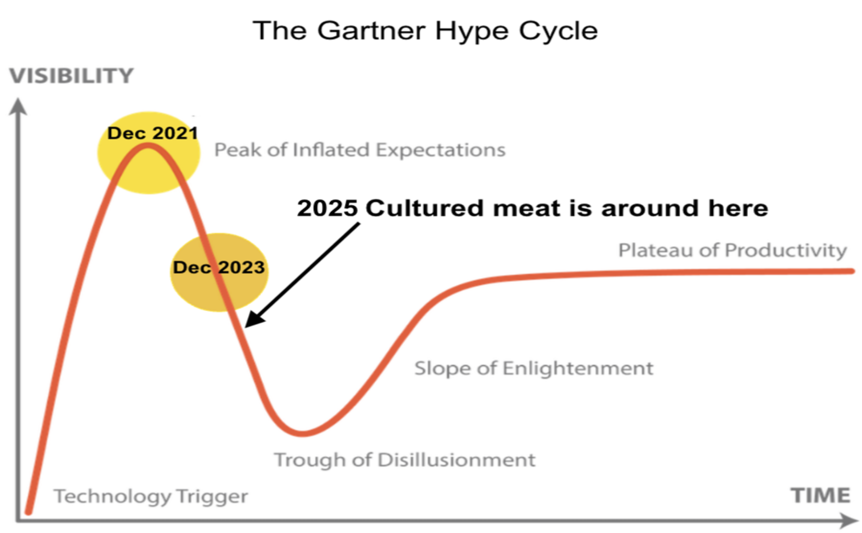


Figure 2. The Gartner hype cycle for the CM/CSF sector. (adapted from New Harvest 2023)

Figure 3 shows a typical "valley of death" as described by the US National Institute of Standards and Technology (NIST) for developing a technology in the biomanufacturing industry (Lee KH, 2020).

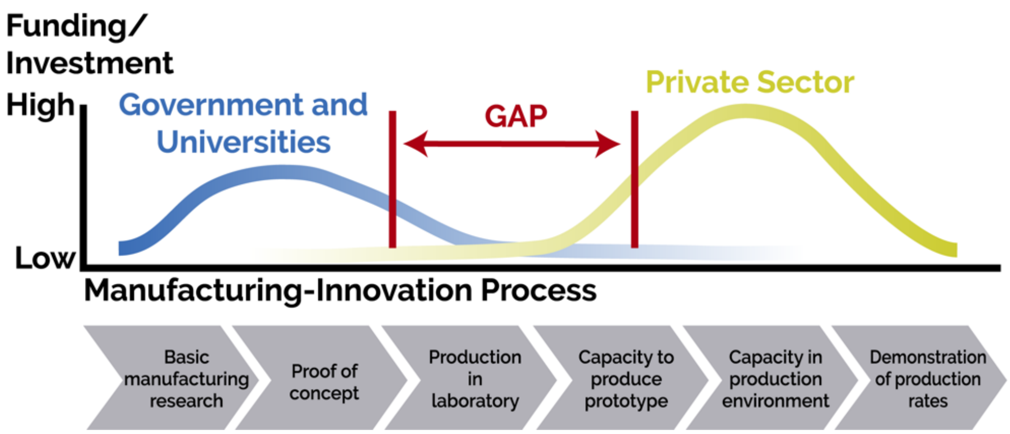


Figure 3. Typical funding gap "valley of death" for biomanufacturing innovation. (figure from: Lee KH, 2020)

Figure 4 (upper half) adds to this by showing how the CM/CSF sector has differed from the typical model, with private investment occurring earlier than usual.

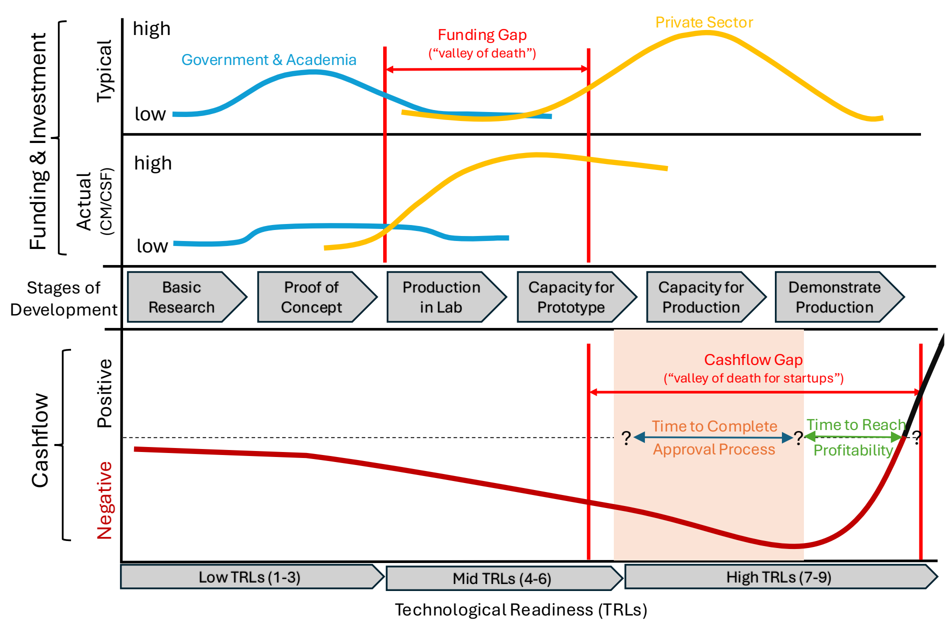


Figure 4. The extended "valley of death" facing CM/CSF development. The upper graph shows both the typical funding profile and gap seen in biomanufacturing innovation (upper half, adapted from Fig 3), as well as what actual investment profile has been with private sector entering earlier (lower half). The lower graph shows cashflow during development of CM/CSF, including the need for an approval process before sales can begin and scaling, both of which are variable in length and create a second "valley of death" for startups based on affordability. Together they show the true "valley of death" faced by startups, both in initial funding for tech and then reaching commercialization.

While early private investment may help bridge the usual funding gap it creates a larger financial pain point for startups as they have to endure a larger pre-revenue period, with a cashflow gap which may form a second, or larger and deeper, "valley of death for startups" on the way to commercialization (lower half, Fig 4). The size of the second gap is also affected by the need for regulatory approval to markets as a novel food product, which could be made worse if opponents force it to be treated as a pharmaceutical product.

Some companies in the CM/CSF sector have already failed to escape this valley. Such failures may be considered a natural part of development and that there will be convergence toward "leaders". However, that concept of convergence assumes there is a connection between investment (having money to survive) and the state or viability of technology a company has. It also assumes no loss of valuable information, or efficiency in developing the technology, as companies with their silos of information fold. Neither of these assumptions are certain given the black box nature of startups in this sector.

For parallels with other fields, those working on CM/CSF might look to the fate of another advanced, technology-based sector, the currently popular "artificial intelligence" (AI), for potential worst-case scenarios. Some may think that AI research is new, but it has been around for a long time, having gone through several boom-and-bust cycles. One "chain reaction" of disillusionment led to such reduction of investment that it stalled the AI sector was likened to a "nuclear winter" by some in the field, and it is generally accepted that there has been two major "AI Winters" in its overall history, one lasting a few decades that ended only recently (Wikipedia (AI Winter)).

Given the current trajectory of funding in the CM/CSF sector, and recent examples of global market and supply chain upheavals, a strategic plan should acknowledge that this could be its fate, and not that it will naturally rebound out of the trough. It should consider if there are mechanisms that can break an unjustified, out-of-control "chain reaction" of disinterest, as well as mechanisms that might preserve current knowledge to be thawed out later. In short, how can the sector avoid and/or survive a "CM/CSF winter"?

For those who might feel this take is alarmist, in addition to the "headwinds" against private investment, an arguably natural part of the hype cycle, the sector is also facing a backlash from civil society in different markets. This is true, even though there is no real commercial business being done, or in the case of the EU, an approval to market. Bans have been proposed, some being passed, in several US states as well as member states within the EU (Stevens R, 2025; NALC, 2024; McCullough C, 2024). This means that the sector is facing both falling interest and growing antagonism that could form a "chain reaction" that further effects investment, as well as interest by consumers and policy makers.

3.1.3 Starting point

Taken together, this sets as the starting point for this gap analysis: a promising yet still emergent technological sector, which, though successful in having **achieved regulatory approval to some markets**, is **not scaled-up for relevant commercial activity** and **whose state of development is not well characterized** across potential technologies, **set in an environment of post-peak-hype-cycle interest** from proponents **and growing antagonism** from opponents.

This is not to dismiss the significant work and progress made by startups or academics up until now. Such efforts have made and continue to keep CM/CSF a promising sector. Nevertheless, it is still an emergent sector, showing how much work is needed to establish the technology, and even more effort to deliver on mission goals. **The analysis above does not form an argument that it is impossible to achieve a fully developed CM/CSF sector or that it should not be funded. Instead, it acknowledges the current, documentable state of progress and growing systemic pressures that work against further progress. This underlines the need to** move towards an increase in its maturity, and to **propose actions necessary to support sustainable development of the sector.**

3.1.4 Finish line

The finish line in its most generic sense, where mission goals have been secured, if not met, would be a sector that has matured to the point that it has produced functioning CM/CSF technologies that generate products at relevant scales which:

1) do not involve animal slaughter throughout the process, including support materials,
2) are similar to or better for food safety and personal health than current animal-derived foods,
3) are commercially/socially sustainable, including consumer acceptance based on sensory comparison with conventional food analogues, such that it can/has become part of a future agricultural system,
4) have equal or less negative impact than current animal agricultural methods on the environment, across various parameters such as greenhouse gas emissions, biological waste, and water and land use, to the extent that it mitigates (in combination with other food and agricultural innovations) as a source of negative environmental impact, animal-based food production,
5) allow for reduction of intensive animal agriculture to the extent that it (in combination with other innovations) improves animal health/welfare and significantly reduces or eliminates livestock as a vector for (non)zoonotic disease,
6) are not disruptive of people's lives and livelihoods,
7) include measures to prevent monopolization or other authoritarian control over food production, and
8) improve EU, national and regional food security and resilience to food supply chain disruptions resulting from political, economic or environmental events.

Some predictive models have been produced for the sector, usually in the form of life cycle analyses (LCAs), techno-economic assessments (TEAs), and forecasts of market size. The purpose of these is usually to show the plausibility of, and/or estimate the level of effectiveness in meeting points 3, 4, or 5, while assuming or not dealing with points 1,2, 6, 7 and 8. These extrapolate from current data (often not publicly accessible), or opinions from experts, to describe current or future capabilities by arbitrary end dates based on underlying assumptions of progress. Market forecasts such as those found in the GFI report quoted above (GFI, 2025) (Fig 5), and another report last year by Systemiq (Systemiq, 2024) (Fig 6), are particularly revealing in that they show a wide range of possible outcomes over time, indicating the lack of certainty with technological and commercial trajectories. The Systemiq report has added value for this analysis when it connects different market outcomes by 2050 to differing levels of "ambition" by stakeholders, whether staying the "current course" or pursuing progress with "high ambition" and discussing components that define these levels (Fig 7).

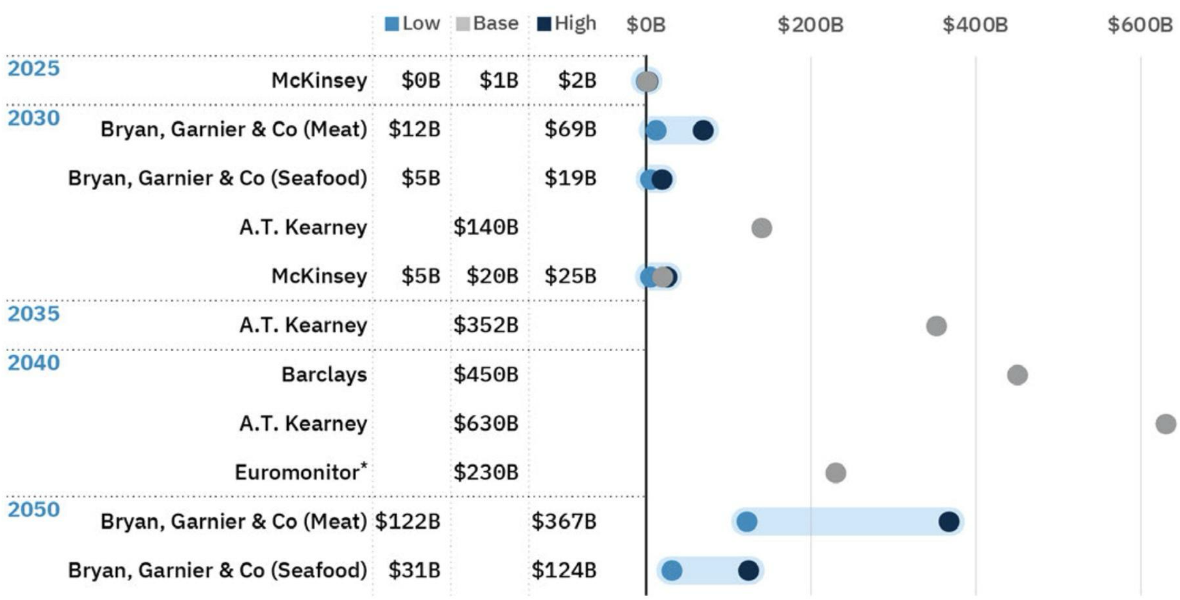


Figure 5. Forecasts for global CM/CSF market size. Sources used in graph: A.T. Kearney, Financial Times (citing Barclays Cultured Meat: Industry funding & facility launches accelerate the path to commercialization," 2022), Bryan, Garnier & Co, Euromonitor, McKinsey. *Some forecasts projected the share of the total market rather than the industry size in dollars. For those forecasts, [GFI] estimated the dollar size of the cultivated meat sector using Barclays' forecast for the total 2040 meat market. (figure from: GFI, 2025)

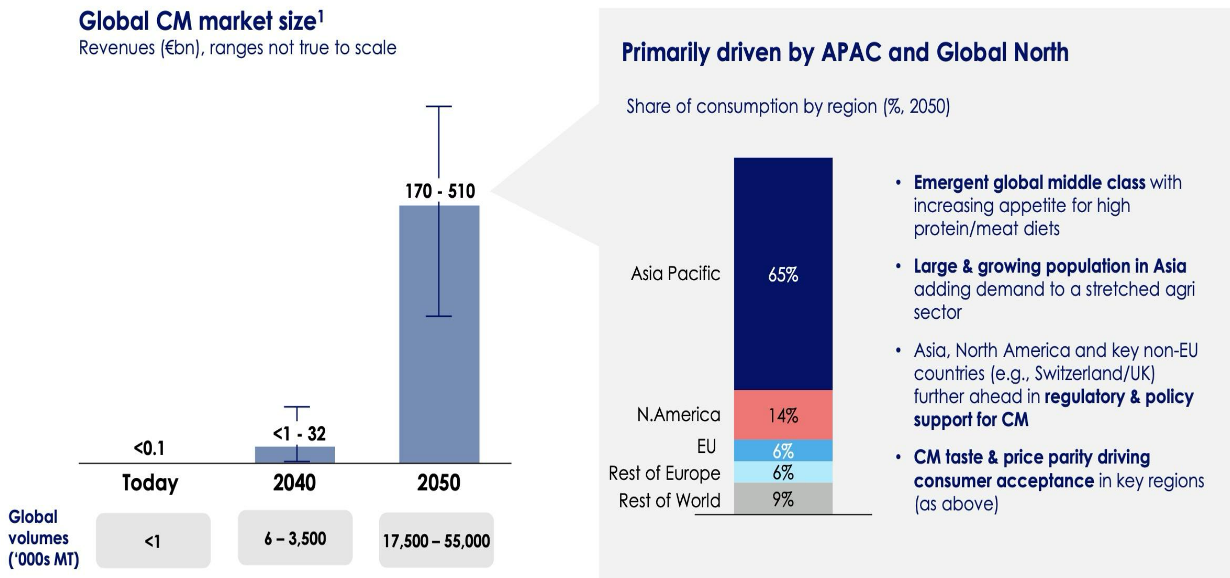


Figure 7. Potential CM/CSF market growth by 2050. Sources & Notes in figure: 1. Systemiq CM analysis; EU cultivated meat opportunity model based on FAO consumption data, Vergeer (2021) TEA of cultivated meat, Ark Biotech (2023) Cultivated meat's path to price parity TEA, McKinsey (2021) Cultivated meat: Out of the lab, into the frying pan, Eurostat Prodcom data; based on medium and high ambition scenarios only. (figure from: Systemiq, 2024)

Current course & speed	Low ambition: CM remains a niche market	Medium ambition: CM & bioeconomy gain momentum	High ambition: CM scales to mass market
• **BAU scenario extrapolating near-term capacity expansions** • Regulatory and political hurdles remain, with few new regulatory approvals granted • Prevents capacity build out and further cost reductions meaning prices stay prohibitively high • Very limited uptake of CM in plant-based (PB) products	• **CM becomes a niche ingredient used in a limited set of PB and high-end products** • Price and performance parity tipping point not met until **2045** • Wider regulatory approvals remain **5+** years out, slowing R&D, scale-up & cost reductions • CM remains expensive, limiting uptake to **0.2%** meat consumption by 2050 – as both an ingredient in PB products (10-20% of product), and some high-end categories (e.g., foie gras, premium seafood)	• **CM gains momentum with tipping point accelerated by traction in broader bioeconomy** • Price tipping point met in **2040** – commoditization of key input supply chains as part of broader bioeconomy sector growth helps bring down costs • Wider-scale regulatory approvals occur within **5** years • CM adoption reaches **3%** by 2050, as an ingredient in PB products and as a replacement for premium products	• **CM becomes a part of mass market diets globally** • Price tipping point met in **2035**, with CM becoming cost effective to include in PB products at high proportions • Regulatory approvals **happen efficiently** across key regions, building off existing frameworks (e.g., Singapore) • CM adoption reaches **9%** by 2050 – forming a core ingredient for PB mass market products, and increasing presence of standalone CM products on the market

Figure 6. Different scenarios for CM/CSF market by 2050. Outcomes for growth of the CM/CSF sector depend on actions taken by the public and private sectors. This figure describes likely scenarios based on current course, low ambition, medium ambition, and high ambition activity. Outcomes are very limited for the sector outside of medium and high ambition activity. These latter scenarios are what were used for growth predictions in Fig 6. (figure from: Systemiq, 2024)

Identifying actions that help break from the current course and facilitate medium-to-high ambition scenarios for the sector are therefore crucial to the strategic road map.

4. The Strategic Road Map

The following section details critical next steps (or initial goals/actions) recommended to be taken by stakeholders who are interested in establishing the viability of CM/CSF technologies, and set the field on an efficient path toward ***all points*** on the finish line.

While these are presented in a rough order of their priority, each may be started now and largely addressed in parallel.

Also note that this plan includes engagement with critics and criticisms, as there are legitimate technological questions as well as how they might impact societies that choose to adopt them. If anything, this plan is meant to encourage an interactive, or co-creative approach.

1. Establish the technology

Core elements have to be established for the sector to be viable.

Cells:

Cells are the fundamental component of CM/CSF technologies. At the very least, **cells meant for food production must be capable of sufficient proliferation** to generate appropriate cell mass, **and** where relevant **differentiation/maturation to appropriate cell types**, such that they are useful at scales relevant for commercial production.

These will likely be cell lines, so that they have proven stability and performance characteristics and do not require obtaining starting cell populations from a source as frequently as primary cells.

While there are cells/lines available for the sector, commercial and non-commercial, **there has yet to be established trusted open access lines**, for non-profit or profit ends, **with proven, robustly reproducible performance. This is arguably essential to show that the most basic component of the technology exists in a practical sense**, with best lines being used as routine "gold standards" for researchers to test other aspects of the technology.

It is not settled whether gene editing/modification is necessary to reach commercial viability, but its use can improve rates of proliferation/differentiation/maturation and potentially reduce need for cell culture components. Convergence on this question would be useful.

Finally, to meet mission goals, cells use for food production should be sourced in a way that does not involve animal slaughter, and preferably with little to no need for removal of source cells in ways that causes physical damage (e.g. surgical biopsy).

Note: This subject is complicated due to the number of animal species, specimens and cell types that could be used, meaning there cannot be a single animal/cell type that is a standard for all. Moreover, in some jurisdictions (e.g. the EU), regulations affecting use of GM or sale of GM products can hinder its use, and thus associated productivity gains from improved process efficiency. Also, for cultures that may exclude certain animals, or require slaughter or specific methods of slaughter as part of religious specifications for certification of food (e.g. kosher/halal), some expectations may be different regarding "mission goals" (see Appendix A) However, these do not change the fundamental need for establishing viable production cells/lines.

Cell-culture components:

Cell culture medium is the second critical component of CM/CSF technologies, used to feed cells and guide proliferation/differentiation. This is where much of the cost can come into production. Improved cell performance and bioreactor/bioprocess design, whether through greater culture media efficiency or medium recycling, can reduce the required amount of medium and/or specific components within it. At the very least, **culture medium meant for production must be sufficiently low cost and**, for mission goals, **without components that pose concerns for food safety, food security or are derived from animals** (e.g. fetal bovine serum, FBS).

While cell culture medium for specific cell lines used for CM research is now commercially available, and some formulations are available in literature (for proliferation and/or differentiation), the **medium still remains at a cost beyond commercial viability.** This is a critical, and ongoing point of research throughout the sector.

In addition, **to be viable long term, and meet mission goals, producing culture medium and so all components within it, must also be feasible from a supply chain perspective at scales that are relevant for commercial food production**. This must take into account not just the existence of primary producers and materials for use, but where production/use of certain components on a scale might impact availability for use in other sectors. This becomes most important for specialized components, like growth factors, which may be used in medicine.

Micro-carriers and scaffolds are examples of non-medium culture components. The need for these has not been established, and will likely depend on the kind of cells or tissues being used and/or produced. **They face the same concerns as culture medium**, both intrinsic aspects (e.g. food safety, animal-component free) as well as commercial viability (e.g. cost & supply chain issues at scale).

Importantly, media formulation, as well as microcarriers and scaffolds materials, should rely on ingredients that foster **food security** and **food supply chains resilience**, in the face of disruptive political, economic and environmental uncertainty and events.

Note: As with cells, this is complicated due to the fact that culture components will usually have to be specific to species, cell-type, cell function, and equipment/process. This prevents there being a singular cell component useful to all. However, this does not change fundamental needs for establishing viable culture components.

Bioreactors:

Bioreactors are the third critical component of CM/CSF technologies, used to house and facilitate the culturing of cells. At the very least, **it is essential to have a reactor capable of growing CM/CSF appropriate cells at sufficient volumes and concentrations**, such that quantities of cell mass are producible at commercially relevant scales, **and for mission goals that no parts are a concern for food safety or the environment**.

Unlike cells and medium components, which still require scientific study of fundamental aspects for proof of principle, **bioreactors are generally well understood and have had a long history use in production processes. This is especially true for stirred-tank bioreactors, which are often used as a model for CM/CSF production. The larger questions here revolve around bringing down costs, especially given the number of steps** (e.g. proliferation, differentiation, maturation, separations, washing, etc.)**, design modifications to suite specific cell needs, and any special techniques that may be desired for production** (e.g. creating whole tissue, 3D printing). For long-term mission goals, **it will also be important to understand their feasibility based on potential supply chain issues** (e.g. amount of steel, or the use of alternative building materials, and capacity to build at required scales).

There has been no convergence on the type of bioreactor(s) which would be the most useful for CM/CSF, though the stereotypical stirred tank reactor has been the most commonly given example. **It may not be important for convergence to happen, given the different cell types and products which may be desired**. That said, **it will be necessary to show that a bioreactor will be able to scale appropriately for commercial purposes.** That will get treated in the next sub-section on production process, still, **many companies do not yet use bioreactors that are at sizes where accurate estimates of scaling are possible**.

Production Process:

A process design brings together the three critical components of the technology, all of them specified to work with each other toward the generation of a specific volume of product. The **key concerns with process design are to minimize financial and environmental costs (including**

land, water and energy use), and these rely extensively on the type of bioreactor(s) used, as well as any equipment and supplies necessary to operate them.

Only after establishing a reliable process design, can accurate LCAs and TEAs be made, which are used to assess commercial viability and environmental sustainability for given process designs, and support decision making from promoters and investors. While LCAs and TEAs have been produced for the sector, most if not all of them rely on theoretical production processes, specifically at scale. In other words, given the low maturity of the sector, currently LCAs and TEAs are being made either to illustrate the potential of specific idealized processes or to support decision making and process design of company promotors and investors, but not yet used to assess established processes built at scale that can provide accurate data to evaluate economic and environmental performance of such processes.

Complexity for process combines aspects mentioned in the first three components, but adds other dimensions of dealing with scaling choices, operation intensification and recycle loops, and process variable control towards performance optimization. In addition to these first three components -cells, media and bioreactors- food formulation, namely texturization and methods to achieve structured products is a crucial part of many final production process steps.

One can scale up, which means having a larger reactor/equipment, or scale out, which means more numbers of the same size reactor/equipment, or a combination of the two. Within those, one can also run single production batches, or have a process that runs continuously. Different unit operations can be run sequentially and independently, or combined and articulated with recycle loops. Variables can be set to constant parameters or controlled dynamically to optimize different objective functions that may privilege economic and/or environmental performance. **There may be no convergence on scaling or batch-style choices**. **However, it will be useful to establish that commercially relevant scaling of the process is practically attainable for both cost and environmental aspects.**

A major challenge for real-life scale-up testing (even to sizes intended for scale-out) is that it often requires a large investment to build such a test system, so much that it may not be considered worth the risk of investing in it when allocated to a single company. This presents funding opportunities for the sector that will be discussed in a later section.

Another challenge for scaling up, is that as size of the bioreactor increases, there is an increased chance for contamination and so loss of production batches. On the other hand, scale out could increase costs for equipment materials and handling.

Products:

Regardless of the exact food product, the **key critical aspects (beyond cost) for a product's viability will be food safety, nutrition, and sensory profile** (organoleptics like taste, smell, etc.). Sensory profile is essential for consumer acceptance and so commercial sale, which is very important. However, **safety and nutrition will determine a product's ability to be sold at all, and**, even if deemed safe, **how it might affect health compared to other choices and so consumer acceptance**.

Despite approvals to markets outside the EU, safety and confirmed nutritional content information for CM/CSF products is generally lacking. The little that has been shared publicly has not necessarily drawn favorable comparisons, instead raising questions not only about relative safety and nutrition, but the use of animal-derived products in medium (e.g. FBS) which is a total mission fail, as well as the composition of the products themselves (e.g. not being muscle or fat, containing a high percentage of plant-based material).

Safety and nutrition data will clearly differ between products, just as current meat products differ in safety and nutrition between those products, but **it would be useful to show more complete and reproducible results for CM/CSF products, especially those without use of animal-derived products in their cell-culture components**.

Products that respect culture heritage and acquire tastes may resonate with different consumer segments and provide adequate entry points for CM/CSF. The use of different media and scaffolding ingredients, sourced locally or through resilient supply chain foods, may contribute to food security and food diversification policies.

Summary:

All aspects of the technology need more work to achieve viability at a commercially relevant scale; cells, medium, bioreactors, bioprocess, and food formulation. **This requires investment into research, education (for expertise), materials, and infrastructure, regardless of TRL.** With a need for more open science, academic research may be preferred, though links can be made between commercial developers and academic labs, as well as through public-private partnerships. Examples of this may be seen in the section on "Opportunities of Stakeholders".

2. Improve data sharing & retention

One of the major factors leading to a lack of public information that could establish the technology is resistance by private developers to share data. As academic research begins to grow likely so will the amount of publicly available information, but it would be useful to encourage private developers to share data as well, and come up with mechanisms that incentive and facilitate sharing by both groups.

Part of this can involve identifying areas of pre-competitive research and collaboration. Another may be to create digital platforms and/or legal instruments which reduce risks that come with sharing.

Another aspect could include improving the quality of data that is shared by harmonizing data collection and formatting to make it easier to compare data between research groups, especially using large-scale analysis of datasets.

Finally, finding ways to retain data, particularly past end dates of projects or after entities close, would be useful to keep results available for future researchers.

3. Establish mechanisms to understand impacts

Beyond making more and higher-quality information publicly available, it would be useful to have convergence for the sector on the methods for measuring or estimating impact, whether environmental or social. There are conflicting studies, and at the very least, to improve public understanding and debate, it would be good to understand the relative merits or shortcomings of different approaches, if not to begin drawing lines on what may be considered acceptable as evidence, analytical technique, and limits of claims from these analyses.

4. Promote standards of practice

Following closely with points 2 & 3, to increase confidence within and about the sector, it would be useful to encourage standards of practice. This could cover data management and handling for research, as well as expectations regarding materials or methods used in production and analysis.

One basic example for production could be a minimal practice of not applying for access to markets for products that used livestock-derived components in the production process (like FBS). Despite frequent claims that beyond ethical reasons, cost issues alone would prevent the use of FBS for commercial products, more than one developer has applied for and received approvals for products that use it. These set bad precedent, and arms critics of the sector. Of course, concerns for animal welfare may differ between cultures and jurisdictions leading to different expectations for standards (see Appendix A).

Setting higher standards/expectations is a form of quality by design for the field.

5. Develop feasible implementation plans that include resource requirements

A lot of opposition to CM/CSF centers on potential effects of its implementation. Beyond negative impacts on health due to concerns about safety and nutrition, treated earlier in subsection 1 on establishing the technology, there are potential socio-economic aspects which aren't linked to the existence of the technology itself, but how it may be implemented. Rather than assuming bad faith with such arguments, it would be useful to ask if there is merit to these concerns.

Where concern ***is not*** justified, it would be good for proponents to understand why it is not justified and that they will likely be required to address such questions as part of trying to implement the technologies. Where concern ***is*** justified, or at least where there are no straightforward existing mechanisms to avoid the outcome, it would be good to consider what might need to be created and work with others wanting to avoid such ends.

A quick example is that with an increase in uptake of alternatives to meat (not just CM/CSF) there may be a decrease in the need for certain workers in the current food supply/value chain. What happens to them is a valid question. That such an effect is not imminent is reassuring, but not a complete answer. It would be useful to work on policies for supporting those who cannot retrain, or retraining those who can and want to.

Beyond direct effects on people, the same holds true for materials required in supply/value chains for the implementation of CM/CSF technologies. Understanding such needs was discussed in subsection 1 above. If and where changes to current supply/chains will be necessary, for example, making sure there is enough steel for bioreactors or raw plants for medium components, policies to make sure they happen in a timely fashion and in ways that do not affect lives and livelihoods will be critical.

Taking potential effects of its implementation seriously, social or otherwise, is another form of instituting quality by design for the field.

6. Establish better comms & approaches

Initial communications strategies and approaches for developing the technology were based on attracting private investment and as such marketing intensive. Putting the hype in the hype cycle. This has helped put the sector where it is now, for better and for worse.

It was unquestionably useful for driving the private investment that initially jump-started the field and most development through today. However, it was not as useful for policymakers, the public at large, or even scientists, trying to understand the actual state of the technology and what it represents. Ultimately, the degree and nature of hype employed have helped fuel the disillusionment and premature opposition we are seeing for this still emerging sector.

Given the current trajectory, it would seem a good time to rethink initial communication strategies and approaches and look toward preventing the chain reaction that appears to be building, which could lead to a CM/CSF winter, while setting accurate expectations for the

future. The following give suggestions for improved communication, to address different issues the field faces.

General improvements

Before anything else, the sector needs to re-center realism over hype. Once the hype bubble has burst, it is time to stop blowing.

It is ok to be excited about the potential of the technology, and express that excitement, but discussions should **stress accuracy** rather than the overly aspirational, being especially careful to **avoid unrealistic timelines and outcomes**. The rebound after the trough is called the slope of enlightenment, and demystification of the technology is key to that.

Part of re-centering **realism may involve reframing CM/CSF technology in a more accurate context**. It is not some singular, silver bullet solution that will disrupt and entirely replace meat and so end livestock-based agriculture. What it can be is **another tool in the agricultural toolbox, another innovation in a long line of innovations** in the food space **offering additional choices to producers and consumers alike**.

That does not mean having to act shy or apologetic, that **the goal is to offer a food product which does not require animal slaughter, and may lessen negative effects on the environment and health**. Quite the contrary. **That *is* the innovation, and it seems like a worthwhile option to give producers and consumers**.

Dealing with the headwinds against investment

Beyond regaining the trust and interest of investors with more realistic timelines, and continuing to excite them with potential benefits of investing in this innovation (GFI, 2025; Systemiq, 2024), the sector can emphasize the unique benefits it offers. After all, CM/CSF shares many of the same benefits as other products in the protein-diversification space. This means that it competes for investment and needs to explain what it brings to the table that is different.

1) Same animal cells = same nutritional profile & benefits

Because CM/CSF is made from animal cells, the nutritional value of proteins and fats should be similar to current, common livestock-based food products. They should also present similar bioavailability and allergenicity.

2) Same animal cells = greater consumer acceptance as meat

In addition to potentially requiring less processing to match taste and texture profiles, they may better meet consumer expectations and so enjoy greater acceptance as meat food products.

3) More controlled conditions = greater food safety/security

Cell culture requires closed, highly controlled production environments where potential inputs, including hazards, may be well monitored. This means that it offers greater food safety and security than most other protein alternatives, and much more than current, common animal-derived food products.

4) Opportunity to lead in biotech research compared to other regions

The high-tech nature and as-yet unproven potential of CM/CSF is a strategic benefit and not inherently a weakness. Nations are currently looking to find advantages they can have in the future world economy. Biotech is one of the areas where Europe can play to its strengths, as some regions still need to develop expertise or material technologies or are losing interest in funding advanced research, particularly in areas relevant to biotech. Securing this would help put the EU in front of biotech research related to food, with potentials for protecting its own food production as well as gaining revenue streams. Losing this would be a needless, self-inflicted wound as the EU is currently in a leading position.

5) Translation to other critical areas of scientific research

CM/CSF technologies come from regenerative medicine. Likewise, discoveries made in CM/CSF may inform other lines of research, including medicine. Whether cells, medium, scaffolding, bioreactors, bio-printing, or overall process design, funding into CM/CSF research can lead to insights and breakthroughs that advance other critical areas of biotech.

6) Use for long term space missions

With an eye toward longer term goals, CM/CSF will be best placed to produce animal food products for long term space missions where the mission is located, as raising livestock will not be possible and providing such products through resupply would be too costly (and risky). And as stated in the previous point, CM/CSF technologies will be relevant for other aspects critical to long term space missions, such as personalized/regenerative medicine.

7) Potential to integrate farmers into high-value novel supply chains supporting the bioeconomy

CM/CSF might benefit some EU farmers and aquafarmers by providing options for transforming traditional livestock and aquafarming into diversified, resilient, and high-value activities. These include supplying inputs for CM/CSF (e.g., cell lines, feedstock ingredients, growth media components, scaffold materials, bioreactor services), partnering in contract-manufacturing or co-production schemes, or even setting up on-site production in a decentralized model. This could lead to diversifying farm incomes, future-proofing operations, creating regional bioeconomies, and building skills in biotechnology.

Note that beyond potential investors, the points above can also be used in discussions with governments and the public to help define additional, unique benefits of CM/CSF.

Dealing with growing antagonism

It would be useful to avoid framing critics and opposition as either painfully ignorant or acting in bad faith and somehow holding the sector back from delivering on its promise. It is true that there are and will be people who oppose CM/CSF technologies out of ignorance or as bad faith actors. However, reflexive framing of critics and potential sources of opposition this way further polarizes the topic, ends the possibility for rational dialogue, and keeps proponents from considering alternative approaches which can address concerns while allowing for innovation.

An early form of this was ignoring and, in some cases, demonizing those in the current animal agricultural sector, treating them as inherently oppositional to CM/CSF (or vice versa), farmers in particular. While it may have played well for investors interested in ending animal slaughter, it set up an unnecessary antagonism with people who are essential to the food system, and created an opening to drag the topic into partisan culture war politics.

A more efficient approach to critics and opposition is to, where possible, engage with them in a straightforward manner. Where critics and opposition present valid points they should be considered and addressed, especially since the technology and forms of implementation have not been established yet. Critics may deliver useful reality checks, reveal gaps in knowledge, and hone communications and approaches. In contrast, genuine bad actors and the willfully ignorant will reveal themselves in this process by choosing to polarize debate further rather than engage in dialogue, and as a practical matter are not the stakeholder groups that are critical to advancing the sector.

By building trust with critics and opponents, it will be possible to address concerns as well as reframe CM/CSF in a more accurate way, which can reduce tensions. For example, **for the technology itself, it may be possible to explain the difference between stem cells and cancer cells,** and so refute claims made about this. **And for its implementation, it is not expected that people who produce or enjoy livestock-based products should be forced to adopt CM/CSF for themselves**, but that **CM/CSF should be allowed to exist as a choice for food producers and consumers**.

Engaging with governments for positive actions

Dealing with governments openly and honestly is the best path forward.

It is time to stop framing regulators as a major block to the success of the technology. As if, but for these backwards regulations, dossiers would already have been submitted and products on the shelves doing their work. The reality is that **government safety regulations and regulators are not the main barrier to significant commercial sales and delivering on potential for CM/CSF**.

If that were the case, there should already be significant sales seen in the jurisdictions where products have been approved. This has not been seen, nor were approved processes shown to be commercially viable, much less able to address key mission goals on sustainability or animal welfare. It is also telling that many developers began switching proposed products from 100% CM foods to hybrid products (mixed with plant-based materials) or as ingredients prior to submission.

This indicates that **deregulation cannot solve the real problem, which is that the sector still needs to establish the technology at TRLs relevant to meet critical performance expectations**. Once a specific technology/process is established to appropriate TRLs, it should be able to produce material at rates, levels, and costs that do not make creating dossiers, or waiting for their approval, as prohibitive as is sometimes made out. In fact, it is the lack of maturity of a technology which can drastically increase the cost and prohibitive nature of entering a regulatory pathway.

This is not to say that reforms of regulatory processes could not or should not be improved to make them more efficient, and to facilitate innovation. They can and arguably should, particularly in Europe, which will be discussed later in this plan. It is just that it does not help interactions with the government, on this and other topics like funding, to take such an antagonistic position. It also feeds into narratives that seek to paint the sector as engaged in capturing regulators to rush unsafe products onto the market. **The sector should be building confidence in regulatory bodies, to help build public trust in their own products' safety, not tearing them down**.

This kind of messaging and approach has also worked to undercut accurate understanding of why and where funding is most needed for the sector, whether by the government or private investment. If significant commercial sales are right around the corner, only needing approvals to start them, then **the image projected is that funding would only be necessary for scale-up at higher TRLs. The reality is that public funding for the sector would still be useful, arguably necessary, at low TRLs**. Yes, it would also be good to have support for scale-up work, especially testing facilities which will be discussed later. But there remains significant work to be done at earlier stages of development.

In Europe, there is an exception to the argument being made so far, when it comes to genetically modified (GM) CM/CSF products. Ironically, this tends to be overlooked with the sector's focus on blaming the relatively easier and faster novel food (NF) regulations**. The EU, and a few other non-EU nations, treat new products containing GM material as a separate category with greater regulatory burdens. Some CM/CSF products will include GM and so will fall under GM rather than NF regulations, and those can present a significant barrier to access**. This is particularly true if a company is looking to compete with another company which is able to use the NF pathway. This has already been seen for a plant-based meat alternative, with the US company Impossible unable to sell its burger in the EU (while already sold at scale for years in the US and elsewhere) due to a lengthy approval process for a single ingredient made through precision fermentation.

Beyond new legislation, such as the upcoming EU Biotech Act, **the EC and member states can be approached to consider alternatives to simple de-regulation. Solutions to build confidence in product safety, as well as allow tastings prior to approval, might be found in working with governments to create regulatory innovations such as "sandboxes" which do not impose as great a burden on regulatory agencies or private developers alike**.

In summary...

At this moment it is important to shift focus to establishing the technology and prepare for how it can be implemented, rather than simply increasing excitement around its potential to draw investment.

That means dealing with the actual status of the technology and realistic timelines while reframing it more accurately, not as a cure-all that must be adopted so as to disrupt systems but as a tool which can be added to a future agricultural system, adding choices for producers and consumers alike, with potentially unique benefits as it is adopted alongside other innovations in the food space.

Critics and oppositional voices should not be ignored, sidelined, demonized, or framed as inherently problematic. They should be engaged with honestly to demystify the technology, depolarize dialogue, and find common areas of concern that can be worked on together. An open approach to other stakeholder groups may result in solutions and reduce tensions, which is not as likely with a closed, circle the wagons around the sector, adversarial approach. By building trust with the public, it will be easier to address misconceptions.

Governments and regulatory agencies should not be framed as a problem, and instead approached as potential partners for solutions. This is innovation and as such old rules may not be fit to purpose, or as efficient as they could be, for an emerging technology. Funding targets can similarly be reset to accurately focus on research needs at low TRLs as well as platforms for scale-up.

4.1 Opportunities for stakeholders and examples of actions taken by them

Work performed in line with each of the points mentioned on the strategic road map can be found throughout the sector. It is not that such work has not existed in one form or another, or does not exist right now. The strategic road map is just a guideline to suggest that it would be useful if these topics were more commonly identified or emphasized practices, critical goals to be achieved in the near to mid-term, and synergies found to work on them between entities, rather than duplicating work alone.

The following subsections point to opportunities emerging from the road map, available for three different stakeholder groups: **1) commercial developers of the technology,** which include startups, established companies, and investors, whether in production of CM/CSF products or support roles (such as material suppliers), **2) non-commercial developers & facilitators**, which include academics, non-profits, NGOs, and additional philanthropic efforts, and **3) governments,** which include policymakers, agencies, and regulatory bodies at all levels (national, regional, local, etc.).

Examples of past or ongoing work aligned with the strategic road map will be given for each group of stakeholders. These will not be comprehensive lists. They do not show all the work being done on topics within the road map, whether by each stakeholder group or by any specific entity mentioned in an example (all of which have done much more work than mentioned here). Rather, these examples are select cases showing that such work is possible and so the kinds of opportunities which are available, to be joined, added to, or emulated. The author apologizes in advance to all organizations for any and all relevant work not cited in the following sub-sections.

Where examples include more than one stakeholder group, work will be described in more detail for the principal stakeholder group that initiated or primarily led the work.

Finally, since establishing better communications and approaches are open to all, and don't require as much directed or intensive effort to achieve, that point will generally not be addressed within the subsections, which is not to suggest that it isn't important or that it is not being done.

4.1.1 Commercial developers

Given the time, effort, and money invested into technological development by CM/CSF startups, they are the best placed to lead on any of the points of the strategic road map, especially establishing the technology.

However, IP concerns and initial interests in vertical integration have created hurdles to data sharing and collaboration. Required disclosures from regulatory approvals and limited publications in journals have not been sufficient for an accurate understanding of the status of the technology by the public. Realistic estimates to reach commercial viability, as well as delivering on mission goals, have also remained elusive.

Most startup-initiated activity involving shared information and collaboration has centered on public relations or lobbying efforts around deregulation and increased funding. This is not to say that startups have not been involved in collaborative work beyond these points, just that those have usually been initiated and/or led by others. Recent shifts away from vertical integration may lead to an increase in startup-initiated activity.

Commercial businesses that provide support for startups, such as suppliers of cells, culture medium components, and bioreactors, have been more likely to share material or performance data. This has also been limited by IP concerns, and in any case has not been enough to establish technological baselines for the sector.

The greatest opportunity for commercial developers is to find ways to begin sharing data and/or materials in a way that increases speed of development and establishment of the technology. Investors can play a critical role by recognizing the utility of shared work on common problems, areas for pre-competitive research and collaboration, and incentivizing such work for companies they support. Even if this work would not be initiated and led by the commercial developers themselves, they could seek out or be open to opportunities emerging from other stakeholder groups.

Two areas of pre-competitive research and collaboration which were recognized early on by commercial developers, and for which they participated in work initiated by others were food safety and developing standards of practice. These were led by non-profits and will be treated in the next sub-section.

Some have also joined with government funded projects, working inside consortia on various points related to the strategic road map, as the commercial partners present within FEASTS are doing. This will be treated in the sub-section on governments.

With growing efforts by the next two stakeholder groups, such opportunities are likely to increase over time, which commercial developers would be encouraged to take advantage of.

One arguable example of work initiated and led by a group from industry, and so will be mentioned here, is development of standards of practice for the sector. This effort was launched by the Japanese Association for Cellular Agriculture (JACA, commercial industry group) in its early days. JACA is harder to pin down as strictly commercial, since it started as a voluntary group, and has been connected with academia and a ministry of the Japanese government, before officially registering as its own entity. Regardless, in addition to other work it has conducted, it worked with members of academia, non-profits, governments, and commercial developers to consider guidelines for producing CM/CSF in the Japanese market, attempting to hit higher standards than might be expected by regulators in order to build public confidence and avoid a backlash. These efforts could be adopted or adapted for other regions and by other stakeholder groups.

4.1.2 Non-commercial developers & facilitators

Entities that are non-commercial, that lack concerns for protecting potential IP, are better placed to initiate and lead efforts that involve the production and sharing of relevant technological information and materials. They are also freer to deal with aspects of implementation, longer term socio-economic or ethical dimensions, that would not be a top concern for commercial developers. As such, non-commercial developers and facilitators are often useful bridges between commercial developers, governments, and the public at large.

Within this section, examples given will be work initiated and led by non-commercial developers and facilitators themselves, which are not based on government funding for specific projects. Those that involve government funding for specific project-related work will be treated in the following sub-section on governments.

Academic groups are able to work on all aspects of technological development, particularly basic (TRLs 1-3) and translational (TRLs 4-6) research, as well as aspects of implementation. The sharing of data and materials occurs naturally within research environments. In many cases this is supported by government funding.

One recent example of an academic-led initiative, not tied to government funding for a specific line of research, is ACCELLERA (the Association for CellAg Cell Line Engineering Research Advancement). This is an informal research association that incentivizes information sharing about cell lines used for CM/CSF, particularly methods to enhance performance. This was started by researchers at TU Delft (Netherlands) and Tufts University (US) and is open to relevant participants across stakeholder groups.

Recently, academics have called for an "Asilomar" style conference for the CM/CSF sector (Bottini et al., 2023). This references a major conference by diverse experts to set guidelines for the use of recombinant DNA. This could be led by academics, non-profits, or commercial entities (see previous section, referencing JACA), though it will be critical for representation beyond private developers in order to build trust in its recommendations.

Non-profits, usually backed by philanthropic donations and not as tied to government funding for specific lines of work, are generally freer than academics to start and lead initiatives over a diverse range of topics.

The safety of CM/CSF, especially with regard to regulatory concerns, is a clear target for low-or pre-competitive research and collaboration for the sector, being a concern for all and critical to establishing the state and viability of the technology. New Harvest (NH, a non-profit) and Vireo Advisors (commercial support/consulting) initiated the cultured meat safety initiative (CMSI) with phase 1 involving interviews and workshops with many startups, who shared information about processes relevant for food safety. This led to the first paper on CM/CSF safety (Ong et al., 2021), which was followed by a second paper produced during phase 2 where government regulators shared their views on safety issues (Ong et al., 2023). Similar workshops were conducted by the Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO), with expert opinions coming from commercial and non-commercial developers, including members of NH and Vireo Advisors. This resulted in a third paper on the topic (FAO&WHO, 2023). Currently, CMSI is in phase 3 and has broadened its interaction to more stakeholder groups.

Modelling the viability and sustainability of CM/CSF technologies is an important and rather hot topic for the sector. Mechanisms for assessing this, data that is relevant to use, and results obtained have been debated in print, whether for TEAs or LCAs. The Good Food Institute (GFI, non-profit) commissioned a TEA for CM/CSF from CE Delft (Commercial support/consultant, Netherlands) (CE Delft, 2021), as well as partnering with GAIA (non-profit) to commission an LCA (with GFI co-authoring) from the same consulting group (Sinke et al., 2023). Beyond the results of these studies, this represented a significant effort, having involved data-sharing from many commercial developers, including five CM startups.

Identifying bottlenecks and opportunities to solve them, whether for the development or implementation of technologies, is important. Planet-bio (non-profit, Netherlands) launched an initiative to tackle these issues for the alternative protein space, including CM/CSF, known as Protein Port. This is an interesting example as it focuses on regional challenges, specifically within the province of South Holland, and involves commercial developers as well as other stakeholders.

One success story, for national level work by a non-commercial developer, is from the Cellular Agriculture Netherlands Foundation (CAN, non-profit, Netherlands). It is was formed by a collection of stakeholders, working to secure a portion of the Dutch National Growth Fund to support the field of cellular agriculture in the Netherlands. They were successful in raising €60M (€80M with private matching funds), which was made available for educational and research programs across the country, as well as open-access scale-up facilities for the sector. Scale-up testing facilities for CM/CSF developers opened this year and will hopefully act as a model for this type of vital work in other countries. Beyond funding crucial aspects of developing the technology, CAN supported a motion by the Dutch government to allow tastings of CM/CSF prototypes, without requiring a safety assessment by the European Food Safety Authority (EFSA, government agency) or approval to market in the EU. Instead, safety for small-scale tastings was assessed by a group of experts who reviewed production protocols, with the review process overseen by CAN. This could be considered a form of regulatory "sandbox" set up in the Netherlands, which saves time, effort and money for all involved, compared to obtaining regulatory approval for the same result, and could be adopted or adapted by other member states. Intriguingly, the first tasting allowed was of a prototype from Meatable (commercial developer, Netherlands), which was GM and so would face difficulty getting approval in the EU.

Finally, to represent **additional philanthropic efforts**, Jeff Bezos started the Bezos Earth Fund (non-profit), with recent openings of a Bezos Center for Sustainable Protein in three different regions of the world, the closest one located at Imperial College London. The fund is reported to represent a $1 billion "commitment to food transformation" in service to environmental concerns, including a $100 million commitment to "developing sustainable protein alternatives", of which CM/CSF would be a part. The center in London is led by an academic group at Imperial College, and will engage stakeholders across the sector on many aspects related to technological development. It is hoped that this will find synergies with many existing initiatives and projects within Europe and other regions, including government-funded projects within the UK.

From a strategic perspective, a note of caution with respect to philanthropic efforts like this last example, particularly if tied to an individual, is that 1) funding can change based on changes in markets that affect the philanthropist, making them less secure to some extent than government funds, 2) if the philanthropist is politically engaged and/or has business interests that might (appear to) benefit from the results of research that is being funded, there is a potential for backlash of some kind from the public, and 3) (if benefits turn out to be more than an appearance) there is the potential for undue influence over resulting technologies, including how it is implemented. This is not to suggest that any of this is the case with Bezos Earth Fund or the newly opened centers, but to point out that this kind of philanthropy (or commercial development tied to a specific individual) comes with some risks unique to its nature, as has been seen with fellow US tech billionaires Bill Gates, and more recently Elon Musk.

4.1.3 Governments

Governments have opportunities to address points on the strategic road map through policy making, which shapes the nature of labelling, regulatory activity, taxation, subsidies, and other choices in funding. The cumulative effect of government action will both create and determine the growth and success of a future CM/CSF market. However, it should be noted that decisions by policymakers can be affected by factors that conflict with innovation and market creation, and decisions in made one administration may not remain stable over succeeding administrations.

Two examples of pro-innovation government activity were already mentioned in the previous sub-section, where the Dutch government, in conjunction with efforts of the non-profit organization CAN, has led to tastings of CM/CSF products, as well as funding for education, research, and scale-up infrastructure.

Pro-innovation activity can also be seen at the European Commission. There have been several projects funded to better understand new food technologies, including CM/CSF, particularly within the Horizon Europe program for research and innovation. Some examples are FEASTS, LIKE-A-PRO, and GIANT LEAPS. These projects have initiated research to address aspects of technological development, as well as investigate potential impacts on the environment, human health, and society based on its adoption. It might be noted that this was done in advance of demands being made for such information by opponents seeking to ban or otherwise restrict CM/CSF. One recently launched Horizon Europe-funded project (APROVALS) may help explore avenues to speed innovation similar to that seen within the Netherlands, particularly creating "sandboxes". Regulatory sandboxes in particular can help share information with regulators, consumers, and policymakers in a way that can increase awareness of CM/CSF products while potentially decreasing time requires for review.

At the level of departments and agencies, coordinating activity by DG RTD is working to help ensure information is shared across such projects, an interest (and effort) that is shared by project leaders (including with similar projects outside of the EU).

Further, EFSA has been working on outreach to stakeholders to develop guidance for the sector, including workshops with experts (e.g. EFSA Scientific Colloquium 27). It may be hoped that work like this, combined with efforts by DG RTD and the EC, can result in more efficiencies being found in the NF regulatory pathway. One aspect that would be particularly useful is pre-submission dialogues, which help cut down on lost time and effort, by allowing for information sharing by an applicant while a dossier is being built. In the UK, the FSA (their version of EFSA) has already initiated a program for developing a sandbox approach, which will allow some level of pre-submission dialogue and could be tested in the EU. Another useful opportunity would be to begin collecting lists of materials, particularly media components, that would be considered safe based on prior testing/knowledge. This being similar to lists used for pharma.

There might also be opportunities for governments to improve efficiencies in dealing with new technologies, particularly those that are interdisciplinary by their nature by forming working groups or a task force made up of members from relevant ministries, departments, and agencies. This could focus dialogue and build knowledge in one place rather than having duplication of efforts in separate governmental silos.

When looking to other European nations regarding project funding, the UK has likewise invested in projects that cover technological development as well as potential societal impact. Representing the former, is the Cellular Agriculture Manufacturing Hub (CARMA project) which empowers CM/CSF research by academia and commercial developers. And representing the latter was the recently completed Cultured Meat and Farmers research project, which engaged farmers about potential impacts from implementation of the technology, as well as seeking opportunities, and resulted in a report that will hopefully be built upon in coming years both within the UK and in other countries (MacMillan et al.,2024).

Outside of Europe, and with an eye towards building infrastructure, the Canadian government has funded the Cellular Agriculture Prairies Ecosystem (CAPE) project. The consortium involves non-profits, academics, and commercial entities working towards "transforming local agricultural resources into biomanufacturing inputs while enhancing talent development and research infrastructure to enhance economic opportunities", with the goal of "agricultural circularity, reducing food production emissions, and adopting local crops and supply chains to decrease reliance on unsustainable imported goods, while building a resilient, locally driven food system" (quotes from New Harvest website).

If sufficient momentum builds for more direct EU funding to support technological development of the CM/CSF sector, both CARMA in the UK and CANS-related projects in the Netherlands might be used as models to adopt or adapt. In that case, it is important to emphasize that funding research to establish the technology remains just as vital at low TRLs as scale up research at higher TRLs. Shared, open-access facilities would be a cost-effective method for scale-up research, especially if existing facilities can be used or repurposed, rather than building new ones. Given the need for greater data sharing, an emphasis on open science is recommended for government funded research. Likewise, learning from public-funded innovation models described by research into other sectors, it would be useful to treat such investment with an eye to a return for taxpayers, rather than just backstopping losses for private investors (Mazzucato, 2020).

Figure 8 summarizes some of the "top-line" opportunities that governments have to positively impact innovation in the CM/CSF space, based on the "valley of death" image presented earlier in figure 4 of this report.

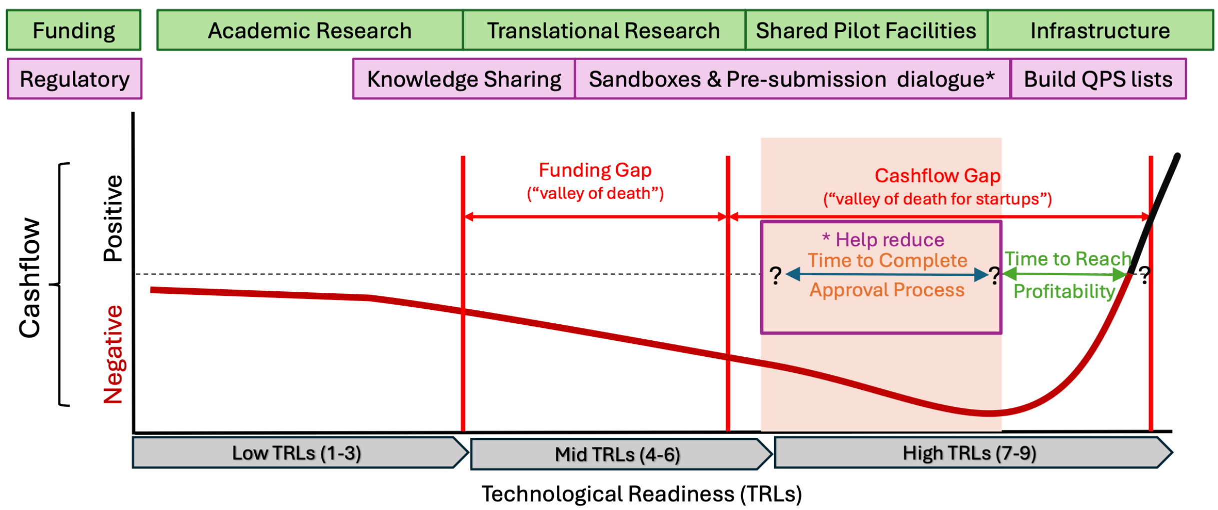


Figure 8. Top-line opportunities for government action to impact CM/CSF sector. Opportunities categorized by funding and regulatory activity, and ordered relative to stages of development. Activity that can shorten the approval process and improve public confidence, without impacting safety, reduces the cashflow gap which can help start-ups survive the second "valley of death."

4.2 Comparison with a national-level strategic road map

The strategic road map presented in this report should not be considered the only or definitive road map for the CM/CSF sector. A useful comparison would be with a strategic road map designed for the CM/CSF sector in Finland, recently published by the VTT Technical Research Centre of Finland Ltd (Siesto et al., 2025). Their road map consists of eight points targeting needs for growing commercial development in Finland, mentioning opportunities for different stakeholders to implement them, primarily tied to government activity.

"[Quote from the VTT action plan online summary:] ...

1. Accelerate investments in infrastructure:
Finland needs an action plan to increase capital investments and attract international companies to invest in Finland. Investing in infrastructure is crucial for enabling new value chains, and the government must create financing and risk loan instruments to facilitate factory investments.

2. Advance regulatory landscape in EU:
Current regulations slow down the development of the industry. Finland shall establish an office in Finland that provides concrete support for the novel food process of cellular agriculture: both financial grants and advisory services. The office should also actively influence the EU to expedite, support, and ease the regulation of new technologies.

3. Launch an RDI programme:
A new 5-year EUR 100 million research, development and innovation programme would produce innovations for the future food system, combining conventional agriculture and cellular agriculture. The goal of the programme is to create sustainable solutions that take full advantage of Finland's strengths... such as its technological expertise and abundant natural resources.

4. Establish a future Ministry of Food:
Propose a joint ministerial working group or organisation to develop a future food system. The organisation would also support the RDI programme and promote cooperation between different sectors.

5. Safeguard future experts for the sector:
The knowledge base should be expanded, and education and training programmes should be developed to meet increasing requirements in the sector. Education and training should produce a wide range of experts and expertise for the food sector, including cellular agriculture and the circular economy.

6. Support consumer communications and enable public tastings:
Providing information on cellular agriculture innovations in a way that captures consumer attention makes it easier for consumers to learn about new products and joint developments. The opportunity to participate in public tastings fosters consumers' awareness of future developments. Novel food tastings organised by experts should be permitted in Finland before market approval.

7. Integrate primary production with cellular agriculture value chains:
Feedstock production and the standardisation of quality for cellular agriculture processes are critical to cellular agriculture value chains and also create new business opportunities

for primary producers. Incentives must be created to enhance cooperation with primary producers.

8. Gear support functions toward exports:
When determining the growth and export potential of cellular agriculture, consideration must be given to production in Finland and its related product exports as well as to equipment, technology and knowhow exports and IP licensing, not to mention the construction of factories and value chains abroad. Support functions should be geared toward all export areas and the situation and developmental outlooks of different export markets should be understood.

… [end quote]"

The above road map could be useful to consider for other member states, or the EU as a whole, when focusing on building infrastructure toward a thriving commercial CM/CSF industry. In each case, the region would consider their specific strengths and needs.

5. Summary and Conclusions

Results of a high-level, generic gap analysis, combined with current trends of declining private investment and increasing public opposition, suggest that disillusionment is setting in for the CM/CSF sector while timelines to deliver on potential remain in the distance.

There is a natural tension between working to build confidence in and support structures for an industry as if it is ready to go (help developers bridge the valley of death), and concentrating on fundamental work that will establish the technology itself more broadly and build trust that it is not hype, or "vaporware," as has been the case in other cutting edge tech industries.

This report takes the position that continued focus on longer term needs of a commercial industry, particularly work that relies on aspirational beliefs about its current status, may continue to feed a cycle of disillusionment which could paralyze the sector for years.

Next steps/goals on this strategic road map are:

1. Establish the technology
Core elements have to be established for the sector to be viable. Reliable cell lines with growth and differentiation capacities appropriate for commercial scale production are essential. Low cost and food-safe medium, with no animal-slaughter derived products, in quantities allowing for stable, commercial scale production is equally essential. To realize sufficient scale-up in volume and cost of production, while also meeting environmental goals, bioreactors and bioprocesses should be designed and validated where material and energy needs are plausible, with minimal waste, including the possibility of medium recycling. Food formulation must meet safety and

nutritional needs, as well as consumer expectations regarding taste, texture, smell, etc. Evidence toward achieving these can lead to convergence on best practices and solutions for the field.

2. Improve data sharing & retention

One of the major factors leading to a lack of public information required to establish the technology is resistance by private developers to share data. Examples of potential work to address this are finding areas of pre-competitive research and collaboration, and ways to exchange data that can still protect IP.

3. Establish mechanisms to understand impacts

Beyond making higher quantities and quality of information publicly available, it would be useful to have convergence for the sector on the methods for measuring or estimating impact, whether environmental, economic or social, including food security and resilience.

4. Promote standards of practice

To increase confidence within and about the sector, it would be useful to encourage standards of practice. This could cover data management and handling for research, as well as expectations regarding materials or methods used in production and analysis.

5. Develop feasible implementation plans that include resource requirements

A lot of opposition to CM/CSF centers on potential effects of its implementation. Beyond concerns about safety and nutrition, there are potential socio-economic aspects which aren't linked to the technology itself. Outreach to those who work to produce and/or desire to consume livestock-based foods, would be an essential part of this. Further, action will be required to ensure that adequate and resilient supply chains are available for the sector during times of political, economic and social disruptions. In this way, the technology can provide food security.

6. Establish better comms & approaches

Given the current trajectory, it would be a good time to reconsider initial communication strategies and approaches and look toward preventing the chain reaction that appears to be building, which could lead to a CM/CSF winter, while setting accurate expectations for the future. Taking a confident position, while re-centering accuracy and reframing the technology as a potential valuable tool (rather than a disruptive silver bullet), as well as seeking outreach co-creation possibilities with governments and even critics (rather than blaming them for holding the sector back), is advised.

Commercial developers, non-commercial developers/facilitators, and governments have opportunities to work on these points together. Some of this can include building support infrastructure for an emerging commercial industry, but that should not be at the loss of vital work in the near term.

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Links to reports used by GFI in graph, shown in Fig 5:

McKinsey report

Euromonitor report

Bryan Garnier report

Financial Times report

Kearney report

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Appendix A

Mission Goals and Cultural Differences

Motivation for investing in CM/CSF can be roughly divided into three main categories: animal welfare, the environment, and financial. A specific investor can have a mix of these motivations, or just one. You can have an investor whose only concern is reduction in animal slaughter and improving animal health (less disease), even if it does not show much improvement toward environmental goals. Similarly, you could have someone who only cares about environmental impacts, even if animals are slaughtered or live poorly. It is also possible a person could even be found that only cares about financial gains coming from innovation, with little care for if it improves anything outside of their bank account. Though in that last case there seems to be little reason for anyone else to build such advanced technology.

From the outset, developers heavily courted investors motivated by animal welfare and the environment. This helped shape initial communications and expectations for the sector, from which the "mission goals " described in this report were derived. But if investors can have different motivations, then not all of the "mission goals" may seem important to them, and so truly goals at all. This can also be true for proponents of CM/CSF who are not investors. In fact, among those who might be willing to adopt the technology, some may find "mission goals" that can prevent them from being able to accept it.

On the individual level, that issue is not significant. Where it does matter is on the societal level, where cultural differences reshape expectations about so-called "mission goals". This could affect development or adoption through social or legal mechanisms.

One of the major differences with respect to "mission goals" is the one about removal of all components derived from animal slaughter, and preferably nothing involving harm to animals. This can be seen very differently, based on social norms around animals or meat.

Religious doctrines about how meat should be made, for example the Islamic concept of helal, may allow for the inclusion of CM. However, it may be required that cells are sourced from a slaughtered animal (Mridul, 2024).

A similar situation exists in Japan, but then coming from social norms about meat production rather than religious doctrines (M. Yoshitomi, personal communication, May-July 2025). Taking biopsies to procure cells could be seen to lessen the health and quality (i.e. market value) of the animal. And since the source animal would likely be slaughtered at some point anyway, it would make sense to obtain cells after, rather than before slaughter. Thus, taking source cells after slaughter could become the norm in Japan, unless there is a strong need from consumers to take a biopsy during their lives. Similarly, other animal-derived components used in the CM/CSF process could come from waste streams, making it more circular. All of this would add value for those in the current supply chain, making them part of the new technology, rather than diminishing them.

Both examples reframe what a "mission goal" to improve animal welfare means. It would not have to be as rigid as excluding slaughter-derived components, as long as the practical result was to lessen the number of animals that had to be slaughtered.

One company, Omeat, caused controversy in the sector after announcing its plan to use animal plasma, obtained from living animals, in place of FBS. The argument in this case was also a reframing of the "mission goal" on animal welfare, in that it did remove animal slaughter, but required ongoing livestock-based agriculture in which animals would routinely have blood drawn. It received investment, showing that there was interest along these less restrictive lines.

The main takeaway from this is that "mission goals" will ultimately be defined by those who develop and adopt the technology. This may differ between societies, or within a society over time. The ones used in this report were taken from the strictest initial concepts described by communications early in this sector's history. There are many who would still advocate for those earlier concepts, as was done in this report, but with an admission that other approaches, if less strict, would still be an improvement from the current situation.

References (Appendix A):

Mridul A. 2024. Singapore's Islamic Council Rules Cultivated Meat as Halal Under the Right Conditions. Green Queen. February 5, 2024

FEASTS
Fostering European Cellular Agriculture for Sustainable Transition Solutions

Recommended reading list

To get a relatively quick but comprehensive overview for specific aspects of the CM/CSF sector, the following reports and documents are highly recommended...

The current state of the sector: GFI. 2025. 2024 State of the Industry: Cultivated meat, seafood, and ingredients.

Opportunities for the EU by 2050: Systemiq. 2024. The EU Cultivated Meat Opportunity.

Diversity and Complexity of CM/CSF Technologies:

FEASTS milestone 8 report - Fernando G; Klingler M. 2025. FEASTS: Cataloguing of available Cultured Meat and Seafood product types and components, supply models and technologies for their production
& FEASTS CM/CSF Process Diagram

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