Futures & Foresight Science

WILEY

ORIGINAL ARTICLE OPEN ACCESS

# Democratization of Tomorrow's Plate: Synergizing Foresight Methods and Design Thinking in Designing Cellular Agriculture Innovations

Simbarashe Nhokovedzo[1] | Petri Tapio[1] | Siyada Witoon[1] | Nikita Uverov[2] | Tawanda Prosper Mushayavanhu[3]

[1]Finland Futures Research Centre, Turku School of Economics, Turku, Finland | [2]Marketing, Turku School of Economics, Turku, Finland | [3]Technopreneurship Development Centre, Harare Institute of Technology, Harare, Zimbabwe

**Correspondence:** Simbarashe Nhokovedzo (nhokovedzos@gmail.com; simbarashe.s.nhokovedzo@utu.fi)

**Received:** 26 March 2025 | **Revised:** 13 August 2025 | **Accepted:** 21 August 2025

**Funding:** The authors received no specific funding for this study.

**Keywords:** cellular agriculture | design thinking | foresight methods | sustainable innovations | wicked challenges

## ABSTRACT

This paper presents a sustainable design framework for cellular agriculture innovations by integrating foresight methods and design thinking. Importantly, the research connected design thinking, foresight methods and sustainable innovations. The framework systematically aligns foresight methods with the design thinking process, thus enabling cellular agriculture innovators to anticipate long-term challenges and navigate uncertainties. The strengths and limitations of either design thinking or foresight are explored thus rationalizing the need to integrate them. A key research question of the study is: *How can foresight methods be systematically integrated with design thinking to enhance the sustainability of Cellular Agriculture innovations?* A user-friendly framework is developed by matching foresight methods capabilities and aims of design thinking stages. The paper discusses theoretical and practical implications of the framework while pointing direction of further research in shaping sustainable food systems.

## 1 | Introduction

> *Design must become innovative, highly creative and cross-disciplinary responsive tool to serve humanity, and we must stop defiling the earth itself with poorly designed objects and structures.*
>
> (Papanek 1984)

The famous quote by Papanek encapsulates the significance of design. Design can be both an enabler and a disruptor of sustainability. It can catalyze transformative sustainable innovation or exacerbate the socioeconomic struggles of humanity through reductionist and short-sighted approaches. In the Cellular Agriculture (Cell Ag) domain, the question of configuring and re-configuring innovation processes are paramount if its promissory sustainability outcomes are to be realized (Glaros et al. 2023). Cell Ag innovation designers have powerful tools and techniques at their disposal, such as design thinking (DT) and foresight methods (FMs) to design sustainable innovations which cater for the needs of present and future generations. The food system Anthropocene is fast unfolding, (Hibino et al. 2024; Jönsson 2020) facing complex sustainability challenges such as climate change, complex global geopolitics, food insecurity and biodiversity loss among others. These mega drivers of change call for a paradigm shift in our food systems. Radical innovations such as Cell Ag are some of proposed solutions for sustainable food production. Cell Ag refers to a group of technologies which leverages synthetic biology (SynBio), biotechnology, precision fermentation and tissue engineering to complement and/or substitute the traditional livestock production and crop farming (Nordlund et al. 2018a). Proponents of Cell Ag position it as a lever to socio-technical transition, claiming up to 96% lower greenhouse gas (GHGs) emissions, 99% less land, 95% lower water usage, reduced biodiversity loss, improved human health and better animal welfare (Gasteratos 2019; Hubalek et al. 2022). However, the field remains a "maybe" industry, (Parasecoli 2022) with a lot of epistemic uncertainties concerning its ethics, technical feasibility, authenticity of sustainability claims, regulatory standards, and human health fears (Hibino et al. 2024). Furthermore, there are concerns with the current Cell Ag innovation processes which some perceive to be not so democratic, raising fears of unjust food system in the future (Moritz et al. 2024a; Moyano-Fernández 2023). The principles of sustainable food systems encompass democratization of food innovation processes (Byaruhanga and Isgren 2023; Wittman 2023) which is claimed to be missing in Cell Ag innovations matrix. Chiles et al. (2021) advocated for democratization of Cellular Agriculture through open participation and transparent ownership of intellectual property associated with it.

Addressing these inconsistencies and incongruencies to sustainability necessitates a democratic, multistakeholder, multidisciplinary innovation approach that embeds the ethos of sustainable and responsible innovation (Parasecoli 2022; Serrat 2010). DT is a human-centric approach to innovation that strives to anchor solutions to human challenges (Serrat 2010). Due to its human centricity, design thinking is considered superior to other innovation approaches like linear and the incremental innovation models (Studer et al. 2018). However, design thinking has its own flaws, (Razzouk and Shute 2012) for instance its presentist-bias makes it potentially capable for committing intergenerational injustices. These insufficiencies compromise its sustainability when employed alone considering how radically disruptive and path-altering Cellular agriculture innovations could be. There are lingering risks of potential lock-ins and irreversible socio-technical transitions that may short-change the future generations forever. It is under such uncertainties that we consider embedding FMs to systematically explore the alternative futures in Cell Ag innovations (Turturean et al. 2011), and tame the DT shortcomings. Given the high complexity, uncertainty and long-term repercussions of Cell Ag, FMs provide a structured way of anticipating risks and opportunities using methods such as scenarios, the Delphi method and Technological roadmapping. Moreso, FMs themselves are insufficient on their own because they lack tangibility (Buhl et al. 2019), thus, integrating the two approaches gives a perfect complementarity for sustainable designing of Cell Ag innovations. As both DT and FMs rely on participatory approaches and collaborative engagements, we envisage a democratized and sustainable Cell Ag designs (Florian. 2024) not only for the present generation but hopefully for the future generations as well.

Despite the hype around Cell Ag and excitement based on speculative imaginaries and polarized narratives, extant research remain skewed towards enhancing technical scalability of Cell Ag, consumer acceptance, projected economic permutations and life cyle assessments (LCAs), (Nyika et al. 2021; Stephens and Ellis 2020a) rather than exploring design and redesign options as essentials to the success of these moonshot innovations. The study attempts to address this critical gap by proposing a sustainable design framework (SDF) that operationalize the synthesis of design thinking and foresight methods in Cell Ag innovation processes. The central research question we are trying to answer is:

*How can foresight methods be systematically integrated into design thinking to enhance the sustainability of Cellular Agriculture innovations?*

To address this question, the study systematically analyses the foundations of design thinking, foresight methods and their link to sustainable innovations. Basing on the unique capabilities of selected FMs to meet the demands of DT stages, we proposed a heuristic selection matrix which yield a democratic innovation process inherited from these two approaches. Finally, we explore the theoretical and practical contributions of applying the proposed matrix and point to future research trajectories in Cell Ag innovations.

## 2 | Reviewing Design Thinking, Foresight Methods, and Cellular Agriculture

### 2.1 | Design Thinking and Its Application in Sustainable Food Innovations

Design thinking is widely defined as a human-centric approach to problem-solving and innovation that is based on understanding the users' needs, thus customizing solutions that are both desirable and feasible (Kelley and Brown 2018). DT originated from the field of designing in response to the rise of wicked challenges in the 1950s, (Rittel and Webber 1973a). It is viewed by some as a strategic tool and a cognitive process that connects the designer with the people and their problems in search of solutions, (Rodgers and Winton 2014; Walker et al. 2019). As design thinking continue to gain popularity over the years, different models evolved such as the Stanford University d. school model, 3i model of IDEO, 7-stage design process of Herbert Simon, the Double Diamond model and AIGA's Head, Heart and Hand model, the TIIDA model (Ljungberg and Skaljo 2023; Thoring and Müller 2011) among others. Despite the differences in terminology and presentation, these models share key features; human centricity, staged and iterative processes, a strong focus on solutions (tangibility) and acknowledgment of ambiguity due to the complexities in the design environment (Buchanan 1992; Carlos and Morimoto 2019; Hagan 2021). For this study, we settled for the Stanford University d. school model which consist of five stages often represented by the acronym E.D.I. P.T, standing for *empathize, define, ideate, prototype and test*. We settled for the Stanford University d. school model because it is widely recognized as one of the earliest design thinking models which bears the founding characteristics of many emerging models (Combelles et al. 2020). We were also attracted by its simplicity in outlining the design thinking process.

As an approach to innovation, design thinking has been applied immensely in food innovations (Zampollo and Peacock 2016). In Norway, (Olsen 2014), successfully applied DT in a seafood innovation project. The project demonstrated relevance of DT fundamentals such as fostering human empathy, iterating early and often, and seeking external collaboration in food value chain innovation. Similarly, Sietsema and others applied DT approach in the context of circular food design, where it was recognized as a powerful tool to enhance citizen participation, foster multidisciplinary approaches in food innovations and improving collaboration (Sijtsema et al. 2020). By embracing its aspect of inclusive engagement, DT facilitates the democratization of food innovation processes (Candel 2022). Parallel to Cell Ag is the rise of insect-based protein as an alternative food source. Interestingly, DT has been successfully employed to improve consumer experiences with insect-based foods (Gallen et al. 2022). Although conventional stages of DT were followed in the insect-based foods project; (empathizing, defining, ideating, prototyping, and testing) to serve as a guiding framework, DT was streamlined into three phases namely exploration, ideation and experimentation. The findings underscored DT's potential to enhance consumer acceptance and adoption of insect-based food innovations While literature acknowledges the application of various DT models in food innovations projects (Castanho et al. 2024), its application in cellular agriculture (Cell Ag) remains underexplored. Unlike in the reviewed cases where DT has been solely applied, we propose that its application in Cell Ag require a more tailored approach which involve integration with foresight methods.

## 2.2 | Foresight Methods, Their Classification and Utilization in Sustainable Food Innovations

Foresight methods are systematic techniques and tools used to explore, create, test, and communicate possible, preferable, plausible and desirable futures to inform decision making in the present (Glenn 2004; Kosow 2008). While futures thinking has always influenced human decision-making (Persson 2024), scholars agree that foresight emerged as a structured scientific field between the 1940s and 1960s (Hines 2020; Kristóf and Nováky 2023) driven by the disruptions caused by the First and Second World War. The utilization of foresight methods has become increasingly important (OECD 2019; UNDP, G. C. P. S. E. 2018) due to increasing complexities in the post-normal age (Sardar 2010). Over the years, foresight has continued to grow as a discipline and its range of methods continue to expand in its toolkit.

Foresight methods can be classified along several dimensions, including qualitative versus quantitative, normative versus exploratory, expert-driven versus participatory, and evidence-based versus creativity-oriented approaches (Puglisi 2001; Glenn 2004; Popper 2008a; Vinnari and Tapio 2012). Selecting appropriate foresight methods is not a stroll in the park as various factors influence the choice, such as the methods' capabilities, the intended purpose, target participants, time horizon of the project, scale of participation, and the need for methodological integration (Popper 2008b). The selection process is critical because different foresight methods offer different strengths and limitations. FMs such as futures workshops excel in engaging participants while others such as mathematical modeling provide data-driven insights. This study follows the classification framework proposed by Rafael Popper, particularly his *Foresight Diamond*, (see figure 1) which categorizes methods based on their orientation towards expertise, interaction, creativity, and evidence (Popper 2008b). We found this classification framework to be highly effective when selecting foresight methods that align with the aims of different stages of DT process. This is because Rafael Popper classified foresight methods according to creativity, interaction, evidence and expertise which is in perfect match with the needs of DT stages of empathize, define, ideate, protype and test. For example, empathizing is easily attainable through interaction-oriented foresight methods, in this case interaction is with people (present generation and future generation envoys) and nature. The ideating stage of DT is achievable through creativity-oriented foresight methods.

Foresight methods could play a crucial role in shaping sustainable food innovations, particularly in emerging fields such as cellular agriculture. Different foresight methods align with various stages of the design thinking process. For example, participatory/interactive foresight methods are highly effective in the empathizing stage (Lambert et al. 2024), where innovation teams seek to understand human needs beyond currently faced challenges such as malnutrition and biodiversity loss. In contrast to traditional innovation approaches such as stage-gate and linear models (Tidd 2006), FMs allow engagement with present challenges while simultaneously anticipating long-term future challenges and opportunities.

In global food systems, foresight methods have been widely applied (Bourgeois 2012) in pursuit of sustainability (Thompson 2018; Galanakis 2024). Organizations such as the Food and Agriculture Organization (FAO) employ techniques such as Horizon Scanning, Scenario Planning, and the Delphi method to map the future of food security (FAO 2015; FAO 2021; FAO 2022). In these projects, foresight methods have been praised for their capabilities in promoting long-term thinking, collaboration, and participation (Prager and Wiebe 2021). In Cell Ag, science fiction prototyping has been applied in a cultured meat project to portray the future narratives due to potential meat industry transformation (Castle 2022). Such methods together with futures images and scenarios narratives generated by FMs is helpful to designers and policy makers in anticipating potential experiences, opportunities and challenges associated with novel innovations. However, the adoption of FMs in innovation has revealed certain limitations, such as inconsistent information and lack of tangibility (Adegbile et al. 2017; Pinter 2013). Furthermore, FMs produce a range of potential future scenarios and images but does not essentially proffer tangible products or solutions. We suppose these limitations can be mitigated by synergizing FMs with DT.

### 2.2.1 | Integration of Foresight Methods Into Design Thinking

Foresight methods are increasingly recognized by scholars as tools for fostering creativity and innovation, particularly with the growing demand for sustainable solutions (Rosa et al. 2021; Sjöblom 2024). Various approaches have been explored to integrate foresight methods into design thinking across different contexts. Schwarz et al. (2023b) highlighted the integration of foresight methods in design projects and provide an assessment of their utilization. Among the commonly used methods are scenarios, science fiction, trend analysis, and expert-based foresight techniques (Schwarz et al. 2023a). However, there is limited evidence on how these methods are selected and matched to different stages of the design process.

Rosa et al. (2021) emphasized the relevance of participatory foresight methods, particularly scenarios, in fostering reflexive innovation. They argued that such methods are essential for addressing wicked challenges by enabling long-term solution development. Løgager et al. (2021) concurred with the relevance of FMs in service designing and proposed a framework for selecting foresight methods based on four key phases of service design: scoping, mapping, mounting, and visioning. Their findings indicate that the choice of methods depends largely on design project objectives.

Though widely used in strategic management, the TIIDA framework (Time, Information, Interpretation, Decision and Action), (Lindgren and Bandhold 2003) is relevant in design thinking (see Figure 2). Ljungberg and Skaljo (2023) acknowledged the relevance of futures thinking in product designing through the TIIDA framework which is anchored in scenario planning.

Our framework builds on these insights, align the needs of design thinking stages to the capabilities of foresight methods as classified by Rafael Popper (Popper 2008b). This alignment aims at simplification of methods selection, hence, enhance the sustainability and effectiveness of design outcomes.

### 2.3 | About Cellular Agriculture and Its Sustainability Innovation Claims

Cellular agriculture refers to a group of disruptive technologies that aim to produce plant and animal-based products from cell cultures rather than directly from plants and animals (Saavoss 2019; Rischer et al. 2020). Cellular agriculture relies on tissue engineering, molecular biology, biotechnology and synthetic biology. Although cellular agriculture is an emerging field, its potential impacts must never be underestimated as it seeks to revolutionaries' production of carbon-neutral meat,

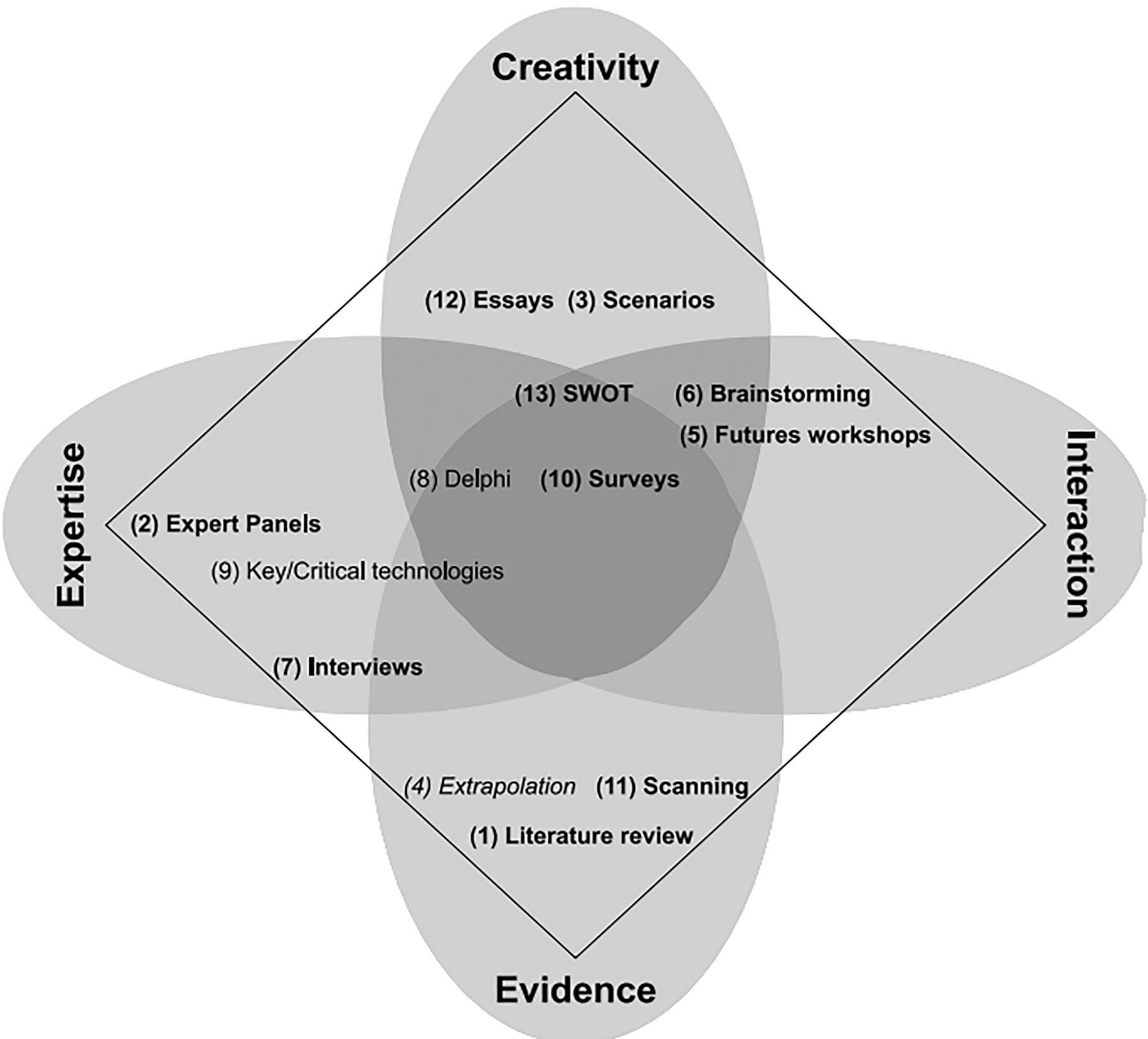


**FIGURE 1** | Foresight diamond (Popper 2008b).

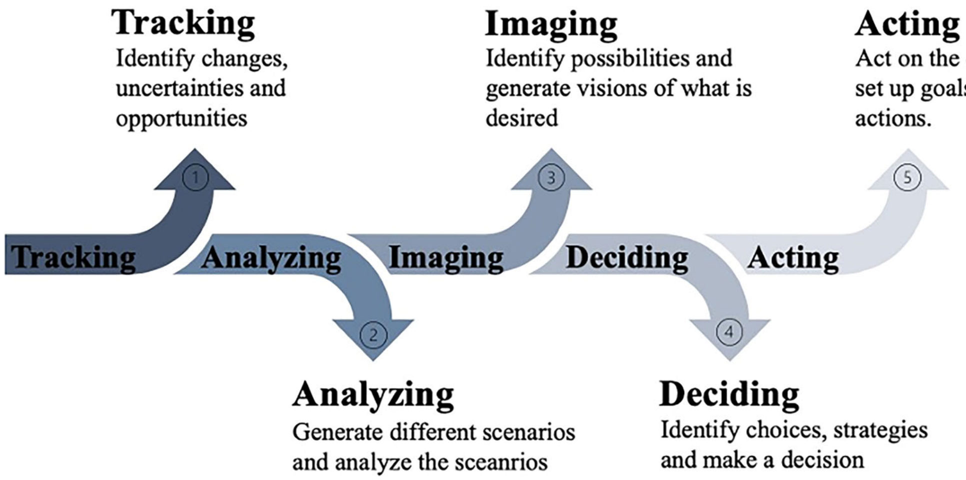


**FIGURE 2** | The TIIDA framework (Ljungberg and Skaljo 2023).

dairy products, microbial lipids, leather, eggs, fish, carbohydrates, wood, coffee, sugar and stockfeed among others (Post 2012; Nordlund et al. 2018b; Barzee et al. 2022). Like any other moonshot innovation, cellular agriculture's potential is shrouded in uncertainties, complexities, hurdles and controversies (Moritz et al. 2022). In some countries cellular agriculture products are banned, for example cultured meat has been banned in Italy, USA states of Florida and Alabama whilst some countries like Singapore, UK and Israel have accepted its commercialization.

The classification of cellular agriculture as a sustainable innovation (SI) is highly debatable (Stephens and Ellis 2020b), to an extent that some scholars dispute even the appropriateness of the name "Cellular Agriculture" itself (Räty et al. 2023; Moritz et al. 2024b). The argument stems from the suffix 'Agriculture' where there is absence of any typical farming activity. Claims are that Cell Ag and nomenclature of its products such as cultured meat are unfairly benefiting from the "goodwill" generated by conventional farming over the centuries (Glaros et al. 2023). To understand the meaning of the term sustainable innovation, one has to disassemble the phrase back to its founding words; sustainable + innovation (Blowfield et al. 2008). The prefix word 'sustainable' has its roots in a German word *"nachhaltigkeit"* with deeper meaning of exploiting without diminishing the prospects of the future generations, and more precisely, (in its original context) not logging timber more than forests could produce (Grober 2007). The widely used term sustainable development encourages meeting present needs without compromising future generation's ability to meet their needs (Hassi et al. 2009), yet the future is not known and cannot be known with certainty even with rigorous foresight. Therefore, in this current study, we posit that sustainability of Cell Ag and the unknown future must be jointly studied because sustainability is *inextricably* defined in the context of the unknown future. It is surprising, even more paradoxical, that sustainable development is framed as ensuring the meeting of future generation needs while so often neglating FMs, Without FMs, mention of future generations risks sounding like a mere rhetoric. Sustainability has three dimensions namely people, planet, and prosperity commonly referred to as the 3Ps (Hassi et al. 2009; Alderin et al. 2016; Severo et al. 2020). The people dimension focuses on humanity's wellbeing in terms of health, equity, education and human rights. Planet refers to environmental wellbeing and minimization of climate change while prosperity refers to just, fair and equitable creation of wealth for humanity (Hautamäki 2010; Visser 2020) On the other hand, innovation is the use of creative ideas and imaginative thoughts to invent or improve solutions (Taylor 2017). From the two words sustainable and innovation, sustainable innovations inherently care about the present and future generations through implementation of creative and imaginative thoughts.

Based on sustainable innovation definition, cellular agriculture may qualify as sustainable innovation based on its *promissory* sustainability properties of reducing greenhouse gas emissions (96%), land use reduction (99%) and reduced water footprint, increased food security and animal welfare advantages (Alvaro 2019; Mouat et al. 2019; Sergelidis 2019 Dueñas-Ocampo et al. 2023). It is important to emphasize that Cell Ag sustainability properties are promissory, thus, they may not turn out as expected (Chriki and Hocquette 2020; Hocquette et al. 2022; Ngah et al. 2023). In this perspective, the sustainable design framework aims for Cell Ag innovations that improve people's health, nutrition, upholding social and ethical consideration of different societies in the present and future generations. On planet, it seeks Cell Ag, which is regenerative, minimizing resource utilization and restore ecosystems. Finally, a prosperous Cell Ag aims towards resilient, inclusive and equitable food system for present and future generations.

## 3 | Connecting Design Thinking and Foresight Methods to Sustainable Designs

Building a strong hybrid framework requires complementarity of the parent models/framework based on homogeneity or heterogeneity of their properties (Gregor and Hevner 2013). Design thinking and foresight methods exhibit both shared and distinct features, enabling their seamless integration into a hybrid conceptual framework. A close examination of design thinking and foresight shows the homogeneity in sharing a common link to sustainability (Kagan et al. 2020). For instance, design thinking has a human centricity principle, which endears itself with the P for people and it address the P for prosperity (through prototyping and testing for economic viability and technical feasibility). On the other hand, foresight has a great concern for people's wellbeing by searching for desirable and preferable futures whilst carefully considering uncertainties, drivers shaping the economic affairs, social and ecological environments, i.e. Prosperity, People and Planet (the 3Ps). Given this shared link to sustainability, integration of design thinking and foresight methods is only logical and well-grounded.

Secondly, design thinking and foresight have shared roots. Undoubtedly, design thinking and foresight are connected in their history as they both grew in prominence around 1940s–1960s (Rittel and Webber 1973a; Wack 1985; Buchanan 1992; Hoyos et al. 2010; Paniagua 2019). seeking to ameliorate the strengthening wicked challenges after the First and Second World Wars. Logically, concepts that emerge at the same time tend to have a lot in common as they seek solutions to related challenges of a specific generation. The term *wicked challenge*, coincidentally common in both DT and foresight was coined by the earliest proponents of DT, Horst Rittel, and Webber (Rittel and Webber 1973b). The term wicked challenge refers to a problem with a vague problem definition, undefined solution, no endpoint, irreversible, unique, urgent, driven by complex systems, not exhaustively describable, have tipping points and regimes among other characteristics (Head and Alford 2008; Remington 2013). The sustainability challenge of malnutrition which cellular agriculture is aiming to mitigate is typically a wicked challenge linked to and driven/by climate change (which is a wicked challenge on its own), socio-cultural, economic, geopolitical, ecological and technological factors which are all intertwined to form complex systems (May 2017). Often, food systems are locked-in and intertwined to many components forming food-land-water-energy nexus and more such nexuses Due to their embeddedness, complexity, uniqueness, and dynamism; wicked challenges cannot be resolved by reductionist approaches but rather by holistic thinking (Remington 2013). Holistic thinking to problem solving involving formation of multi-disciplinary teams and cross cutting collaboration efforts (Schwarz et al. 2023b). It is in this vein that we propose combination of design thinking and foresight methods in designing of cellular agriculture innovations. The perpetuity and continuous nature of wicked challenges (Remington 2013), strongly justifies the use of foresight methods to consider trajectories of wicked challenges under varying conditions and timeframes.

Thirdly, design thinking and foresight methods exhibit homogeneity in their modus operandi. Complexity of change drivers, systems and trends explains the ambiguity faced by designers of innovations when they try to develop solutions to wicked challenges. In dealing with ambiguity, design thinking relies on multidisciplinary teams, repeated experimentation, and iterations whilst foresight count on reframing and use of wild cards when dealing with complexity. Interestingly, both design thinking and foresight rely on multi and trans-disciplinary teams, creativity, mind mapping and workshops when addressing complexity (Victor and Vidal 2014; Rösch et al. 2023). Given the similarities in execution, infusing FMs in DT would eliminate redundancy that would arise from running them separately.

Apart from the commonalities, design thinking and foresight have glaring differences between them which justify complementarity by heterogeneity (Gregor and Hevner 2013) While design thinking's aims at offering a solution to a known problem, foresight aim to uncover future challenges, opportunities and desired futures. Moreover, design thinking is solution oriented as indicated by its tangibility rule (Vikas et al. 2022), which state that tangible solutions must emanate from any design process whilst foresight methods aim to provide alternative, possible, probable, plausible, and desirable futures in form of compelling, radical narrations and future images (Glenn 2004; Sohail Inayatullah 2013) which are not essentially tangible. This distinction strengthens the case for integration, particularly in ensuring sustainability of Cell Ag innovations as foresight visionary images and narratives are converted to tangible prototypes and actionable innovations through DT.

Contrary to the views of Gordon and others (Gordon et al. 2019), who discouraged amalgamation of DT and FMs due to differences in approaches and timeframes, we assert that the heterogeneity between design thinking and foresight should never be viewed as an excuse to integrate them. Rather, these differences strengthen their complementarity by heterogeneity in designing sustainable innovations. The inherent homogeneous aspects earlier mentioned could potentially enhance their gelling for use in cellular agriculture innovations processes (Refer to Table 1 for more details about design thinking and foresight methods outcomes in Cell Ag innovations).

## 4 | The Sustainable Design Framework

Building on the connections of design thinking, foresight, and sustainability, we structured a Sustainable Designing Framework (SDF) using DT and foresight methods for use in sustainable innovation processes. The aim of each design thinking stage was matched with the capabilities of foresight methods selected for that stage as illustrated in Figure 3. In an actual cellular agriculture innovation process, practitioners can choose one method or a few methods from the grouped methods. Design thinking and foresight methods possess both homogeneous and heterogeneous qualities promoting their integration into a hybrid conceptual framework.

Cell Ag innovations are not happening in a vacuum, but in a complex environment, (see Figure 3) defined by driving forces of change, also referred to as megatrends (Thorsen et al. 2025). The megatrends, (labeled as MTs in the framework) such as climate change, population growth, cultural shifts, technological revolutions and shifting geopolitics (Kirova et al. 2019; Thorsen et al. 2025), are unignorable forces in the broader environment of Cell Ag innovations. For exemplification, we chose only five megatrends, MT1-5 to represent their imposing influence on the designing environment of Cell Ag innovations. These megatrends, highly dynamic and intertwined, directly influence *what, how* and *why* questions of Cell Ag innovations. While detailed exploration of how the megatrends influence designing of Cell Ag innovations is beyond the scope of this article, it is important to mention and position them in the designing environment. Amid the megatrends, design thinkers must remain focused on the three pillars of

**TABLE 1** | Cell Ag innovations through sustainable design framework (SDF).

| Design thinking stages | Design thinking alone | Design thinking with foresight methods. (Sustainable design framework) |
|---|---|---|
| Empathize | Understanding present eaters' needs, (Jensen et al. 2016). This could be sensual, textural, nutritional, and cultural issues. Empathizing is democratic through inclusion of present eaters only. Not intergenerational sensitive. | Empathizing with present, future eaters and the planet. Considering future possibilities in multiple futures. Analyses of drivers of change (pain drivers), their dynamics and impacts on present and future eaters plight. Democratic and intergenerational sensitive empathizing process. |
| Define | Challenges/problems are defined in narrow sense of people and prosperity. For example, affordability, inequalities in access and technical issues in production. Cell Ag innovations, for instance, cultured meat designers are all but focused on achieving price-parity with conventional meat. Their problem is narrowly defined in "private cost terms." | Holistic definition of users' problems in present and in the future. Consideration of how the challenges could manifest in multiple futures through iterations and reframing. Defining possible cellular agriculture future challenges and trying to minimize them now. |
| Ideate | Ideas generated from present eaters' groups and entrepreneurs such cultivated food start-ups. Ideas are sound in the short-term e.g. ways of attaining price-parity with conventional agriculture products. | Ideating for multiple futures. Understanding the short- and long-term impacts of cellular agriculture. Inclusion of future generations in ideating. Reframing to test resilience of ideas in multiple possible futures e.g. considering Cell Ag food system under a crippling world war, a pandemic or extreme climate change. |
| Protype | Protypes designed to meet profitability targets. Driven by present consumer expectations on the Cell Ag innovation attributes such as taste, texture, and affordability. Prototypes are designed in linear thinking to meet the current needs. | Rapid prototyping for different multiple futures and time horizons. Protypes are fashioned after defined desired futures for prosperity, people and planet. Developing prototypes that address the intergenerational concerns. |
| Test | Testing to enter the markets. Testing is skewed at seeking acceptance, seeking technical efficiency and profitability. | Testing for present and future needs. Testing for resilience and robustness of cellular agriculture innovations in multiple possible futures. |

sustainability; people, planet and prosperity (3Ps) as their primary cause.

The empathizing stage aims at giving a deep understanding of emotional, affective, shared, and mirrored experiences of people (Gasparini 2015) to inform design process and make sure the solutions are user-centered. However, beyond human-centered empathy, Cellular agriculture design thinkers must extend empathy to the ecological environment (Schultz 2000), by considering how natural environment is stressed when providing food to humanity. This could be through life cycle analysis (LCA) of conventional food systems to assess the stress caused on the environment through multi-disciplinary teams comprising food scientists, farmers, biotechnologists, cellular biologists, ecologists, consumer groups, economists, social scientists, health experts and more importantly future generation envoys. Apart from the observations and in-depth interviews normally employed in empathizing of DT, engaging interactive foresight methods (Popper 2008a) such as citizen panels, future search conferences, charrettes, scenario workshops, stakeholder analysis, opinion polling and other participatory methods could edify the process These foresight methods help designers to think about the current challenges (such as malnutrition) in present and in the future. For example, by using futures scenarios, consideration of alternative futures is possible, such as malnutrition under extreme war, pandemics, severe climate shocks and Artificial General Intelligence gripped societies. This could increase the sincerity of empathizing and future proofing of Cell Ag designs.

Defining the problem relating to Cell Ag range from identifying technical challenges such as cell-culture solution deficiencies, affordability, scalability, nutrition, texture, acceptability, to how they intersect with future concerns such extinction of the natural, extreme climate change and food culture tensions. Defining the Cell Ag problem relies on evidence, hence, the relevance of evidence-oriented foresight methods such as causal layered analysis (CLA), Horizon Scanning, Trend Impact Analysis, Cross Impact Analysis, extrapolations and Bibliometrics studies. For example, designers of cultivated meat and meat alternatives could consider CLA to extract, and analyse Cell Ag issues. The CLA allows the design thinkers to closely analyse the litany, systems, worldviews, and metaphors related to Cell Ag as defined by the targeted groups, regions, or continents (Francis Gomes et al. 2015). As truth is conjectural and relative, CLAs from diverse cultures or regions could yield different evidence to inform designs, re-designs, or iterations along the design thinking process. Horizon scanning possesses

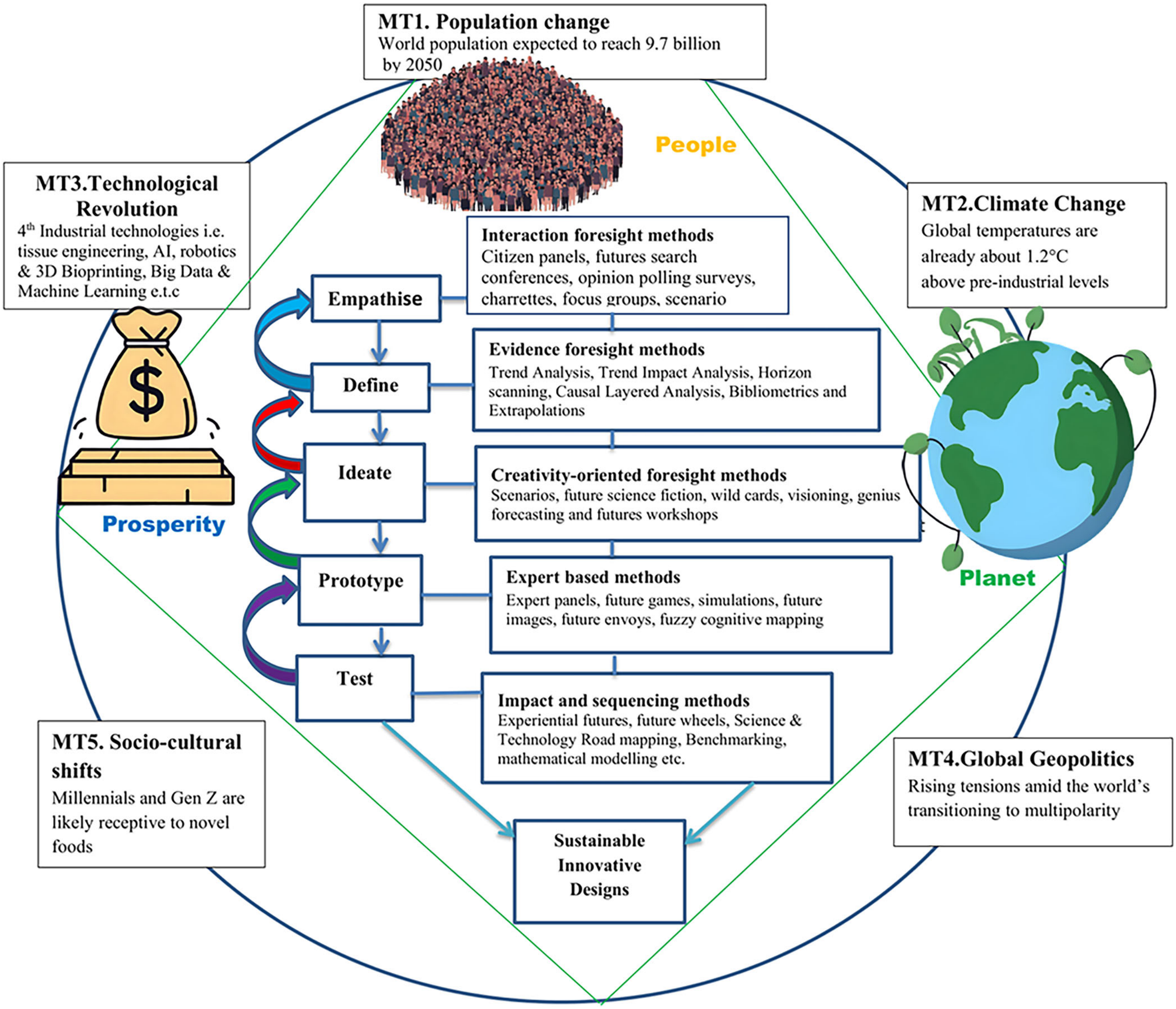


**FIGURE 3** | Sustainable Design Framework, (Authors' illustration, 2025).

qualities for effective problem definition through analysis of signals of change. It allows the cellular agriculture innovators to scan the (Social, Technological, Economic, Ecological and Political) STEEP components identifying weak, strengthening, and strong signals in the context of cellular agriculture (Störmer et al. 2020). Where the statistics are available, designers could employ Trend Analysis (TA) and Trend Impact Analysis (TIA) to understand past, its present and projected future trends of challenges such biodiversity loss or micro-nutrient deficiencies among juveniles in a certain region.

Ideation focuses on generating ideas from creative methods such as use of Backcasting, future search workshops, visioning, and science fiction. The aim is to think beyond the immediate by exploring multiple range of potential futures on what Cell Ag would look like in consideration of change drivers or change inhibitors such as ethical concerns, and cultural concerns,. Tools such as wild cards and black swans provokes a deep 'what if thinking' necessary for resilient ideas. Scenarios and Backcasting help envisioning of diverse contexts and pathways to desired futures. For example, a Scenario of global boom of Cell Ag due to technology advancement coupled with consumer acceptance is different from a Scenario of extreme public distrust of Cell Ag. In these two scenarios ideas about culture medium, ingredients and food texture could be different. Design teams could rank scenarios according to their probability and impact to narrow-down options before proceeding to the prototyping stage.

In the Cell Ag innovations context, prototyping involves modeling and simulating biochemical formulae, 3D-printed cellular food samples, concept models, new cell growth mediums, fetal bovine serum versions, templates, artefacts, schematic presentations, bio-models, and tangible manifestations of speculative futures products build from the ideating process. Prototypes function as drafts and boundary objects that facilitate translation of foresight images into reality. Expert based foresight methods (Popper 2008b), such as expert panels, morphological analysis, simulation games and future imaging could be instrumental in developing and refining prototypes. Considering the emergent and disruptive nature of Cell Ag, rapid prototyping and additive manufacturing (3D printing) could enable fast iteration of models giving immediate feedback loops for approval and refinement. The refinements and approval could be done by both present generations and imaginary future generations. Protypes can be produced quickly through 3D rapid prototyping to produce impactful visuals and models about the future Cell Ag foods. In our sustainable designing framework, protypes for cellular agriculture are for present and the future generations with clear variations, where necessary. Prototyping involves envisioning future value chains and future personas, that are hypothetical representations of future economic and social agents in scenarios such as post-animal markets. The future personas enable the consideration of technological trajectories and socioeconomic dynamics (Stelzer et al. 2020) of Cell Ag, hence guide resilient and sustainably responsive innovations.

Testing serves as a bridge between mock designs and reality. It allows present day eaters and (imaginary) future eaters to taste test the cellular agriculture innovations in real life settings. Designers must balance between demands of present eaters while remaining fair to the future eaters (Weiss 1990) in terms of variety, taste, health, morality, availability of life forms and sustainability (Green et al. 2018). One way of seeking intergenerational equity is the inclusion taste testers from both the current and future generations as imaginary future generation group (Hara et al. 2019). To complement this approach, Impact and sequencing foresight methods such as experiential futures, relevance trees, futures wheel, Science and Technology Road mapping and Fuzzy Cognitive Mapping (FCM) are some of the valuable foresight methods to provide robust analytical framework. For instance, the futures wheel method could be used to visualise the primary, secondary and tertiary ripple-effects of Cell Ag sugar innovation (e.g., allulose) on social, economic, and environmental dimensions. Rigorous application of impact assessing foresight methods to evaluate alternative prototypes is necessary to inform design adjustments (re-design rule) in consideration of future generations.

## 5 | Discussion

The integration of foresight methods into the design thinking process is evolving through diverse approaches as innovators seek to anchor innovation within a future-conscious paradigm (Schwarz et al. 2023a). This need is further reinforced by increasing complexity, uncertainty, and volatility, which demands that innovation processes consider both present and future sustainability (Mayer et al. 2014). We aligned with the broader argument for embedding foresight in design thinking and, more specifically, in the development of Cellular Agriculture (Cell Ag) innovations. However, foresight methods used in design thinking are often selected inconsistently, guided more by intuition than by structured criteria. Our framework attempt to address this gap by systematically integrating foresight methods at each stage of the design thinking process, ensuring that innovation is future-conscious from creative processes.

While our framework builds on existing design thinking models, particularly Stanford University's d. school approach, it extends the DT focus beyond present problem-solving to include anticipating and mitigating future challenges. This feedforward control orientation enhances the resilience of Cell Ag innovations by embedding long-term thinking into each stage of designing. Although authors like (Gordon et al. 2019), caution against amalgamation of foresight and design thinking due to the methodological tensions between the approaches, we argue that their combination enhances innovation robustness, particularly in addressing wicked challenges. By systematically merging the two, our framework encourages Cell Ag innovators to consider both approaches thus minimizing biased preference to one approach. It also reduces costs and potential redundancy that could arise from applying these methods separately.

### 5.1 | Theoretical Implications

The study contributes immensely to the theoretical body of knowledge in the areas of innovation processes and sustainable innovations. Firstly, the study pushes the frontiers of design thinking theory especially the Stanford University d. school model. It challenges the present-centric bias of design thinking. DT focuses on problem solving in the present, (Castanho et al. 2024) thus making it susceptible to presentist-bias which may lead to intergenerational injustices. Integration with foresight methods such as the Delphi method extends the DT's scope to anticipatory problem and opportunity framing. This enables future-conscious innovation processes which are necessary in the case of radical innovations such as Cell Ag.

Secondly, the study strongly confronted the boundary between foresight and innovation processes. Foresight methods are often criticized for being disconnected to actionable solutions or innovations (Salminen et al. 2012). The criticism is logical because foresight is about exploring possible futures which may or may not become a reality. Embedding foresight into design thinking makes future images and visions tangible through DT's prototyping. The research could lead to further discussions in the theory of innovation foresight showing how long-term uncertainties could create opportunities for real-world innovation designs.

Contemporary researchers subscribe to holistic approaches in addressing wicked challenges (Remington and Sonya 2013), which involve use of multiple approaches in pursuit of sustainability. SDF could fit that kind of thinking in respect of malnutrition and neighboring wicked challenges such as climate change and biodiversity loss. Sustainability theories emphasize long-term resilience and democratization of innovation processes (Folke et al. 2002; Pickering et al. 2022) which are both active salient features in our study. We claimed that sustainability, by its concern for current and future generations. should be viewed through the foresight lenses especially in cases of path transforming innovations such as Cell Ag.

### 5.2 | Practical Implications

From a practical perspective, the sustainable design framework can potentially help to reduce costs associated with innovation processes. Radical innovations such as Cell Ag requires huge financial investments into research and development as well as navigating complex regulatory frameworks (Linturi et al. 2022; Nawrocki and Jonek-Kowalska 2022). Including foresight methods in the design process could help innovating firms to reduce the huge sunk costs by carefully exploring future uncertainties, opportunities and risks. Further, the integrated SDF allows one team to undertake both design and foresight work that could ordinarily be done by different teams at different budgets and times. This reduces innovation related costs especially where a firm relies on hired consultants.

Secondly, adoption of foresight in design processes could improve the Cell Ag start-ups' strategic agility (Wach et al. 2024). Integration of DT and FMs potentially increases the strategic agility due to use of future-ready innovation teams that can detect and interpret signals of change in the market (Linares-Barbero and Vega 2024). For example a Cell Ag start-up using SDF can identify emerging consumer preferences through Horizon Scanning, thus quickly pivot its R&D initiatives to gain competitive advantage.

Beyond an individual corporation, SDF can also be applied to analyse the external costs associated with Cell Ag innovations. For instance, methods mentioned on testing stage can assess potential externalities, both negative and positive across spatial and temporal scales. The future wheel is one such a method capable of displaying multi-layered levels of Cell Ag ripple effects. Potential externalities of Cell Ag could be economic displacement of conventional crop farming and livestock production as well as spillover effects on the natural environment. Given the scale and complexity of these mega-risks, foresight methods are essential in design of Cell Ag innovations.

### 5.3 | Potential Limitations and Future Direction for Sustainable Design Research

The foresight informed design framework could potentially suffer from methodological challenges. Balancing the foresight thinking and present thinking might present challenges and cause decision paralysis. We recommend inclusion of dedicated future generation envoys to curtail the presentist-bias and use of dedicated foresight techniques such as the Rip Van Winkle technique to avoid getting stuck in current problems. Also, foresight work often produce multiple futures which are difficult to prototype. To mitigate this limitation, we encourage multi-disciplinary teams which foster iterative feedback loops that allow prototypes to be tested against future scenarios.

On further research, we call for more research on how emerging technologies (4th industrialization technologies), such as Artificial Intelligence (AI), advanced robotics and 3D Bioprinting influence the design function of radical food innovations such as Cell Ag. The call is made with full knowledge that technologies which emerge concurrently have a high propensity to integrate (Heinonen et al. 2017). Therefore, cellular agriculture has an inherent affinity to coexist and grow with other 4th industrial revolution technologies. Beyond increasing the speed and efficiency of design and manufacturing, the combination of Cell Ag with these emerging innovations increases uncertainties on the sustainability of the humankind as technology takes over the food system.

## 6 | Conclusion

The sustainable design conceptual framework emerged from the integration of design thinking and foresight methods, to address sustainability challenges. This study established a strong link between DT and FMs, as both originated from the need to solve wicked problems. Their execution exhibits homogeneity through reliance on iterative processes. Additionally, both approaches thrive on multi-disciplinary teams, making their integration more efficient in terms of cost and time compared to executing them separately. Beyond their similarities, we built an argument for complementarity by heterogeneity, emphasizing their differences on timescale of application. By integrating DT and FMs, the framework reconciles short-term decision-making with long-term consequences, lessening “nowism” in the cellular agriculture innovation process. Furthermore, the ability to prototype future visions from foresight through design thinking strengthens the case for their combination. The participatory nature of both DT and FMs was viewed as a boon to democratization of Cell Ag innovation processes making them more inclusive and future oriented. Finally, the theoretical and practical implications of the SDF were explored, and future research direction was pointed out.

#### Acknowledgments

We acknowledge the Doctoral researchers at Turku School of Economics for their constructive arguments, which contributed to the refinement of our article. Open access publishing facilitated by Turun yliopisto, as part of the Wiley - FinELib agreement.

#### Conflicts of Interest

The authors declare no conflict of interest.

#### Data Availability Statement

The data that support the findings of this study are openly available.

#### References

Adegbile, A., D. Sarpong, and D. Meissner. 2017. “Strategic Foresight for Innovation Management: A Review and Research Agenda.” In *International Journal of Innovation and Technology Management* (14, Issue 4). World Scientific Publishing Co. Pte Ltd. https://doi.org/10.1142/S0219877017500195.

Alderin, C., T. Do, and K. Blomkvist (2016). Sustainable Innovation-Driving Factors in Large Firms. 1–57.

Alvaro, C. (2019). Lab-Grown Meat and Veganism: A Virtue-Oriented Perspective. 127–141.

Barzee, T. J., H. M. El Mashad, L. Cao, A. Chio, Z. Pan, and R. Zhang. 2022. “Cell-Cultivated Food Production and Processing: A Review.” *Food Bioengineering* 1, no. 1: 4–25. https://doi.org/10.1002/fbe2.12009.

Blowfield, M., W. Visser, and F. Livesey. 2008. “Sustainability Innovation: Mapping the Territory.” *Crrc 2008* 44, no. 0: 1–23.

Bourgeois, R. (2012). The State of Foresight in Food and Agriculture and the Roads Toward Improvement. https://www.researchgate.net/publication/235788972.

Buchanan, R. 1992. "Wicked Problems Thinking in Design." *Design Issues* 8, no. 2: 5–21. http://www.jstor.org/stable/1511637.

Buhl, A., M. Schmidt-Keilich, V. Muster, et al. 2019. "Design Thinking for Sustainability: Why and How Design Thinking Can Foster Sustainability-Oriented Innovation Development." *Journal of Cleaner Production* 231: 1248–1257. https://doi.org/10.1016/j.jclepro.2019.05.259.

Byaruhanga, R., and E. Isgren. 2023. "Rethinking the Alternatives: Food Sovereignty as a Prerequisite for Sustainable Food Security." *Food Ethics* 8, no. 2: 16. https://doi.org/10.1007/s41055-023-00126-6.

Candel, J. J. L. 2022. "Power to the People? Food Democracy Initiatives' Contributions to Democratic Goods." *Agriculture and Human Values* 39, no. 4: 1477–1489. https://doi.org/10.1007/s10460-022-10322-5.

Carlos, P., and H. Morimoto (2019). Design Thinking: Prototype Recommended readings.

Castanho, A., C. Brites, J. C. Oliveira, and L. M. Cunha. 2024. "Food Design Thinking: A Systematic Review from an Evolutionary Perspective." In *Foods*. Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/foods13152446.

Castle, N. 2022. "In Vitro Meat and Science Fiction: Contemporary Narratives of Cultured Flesh." *Extrapolation* 63, no. 2: 149–179. https://doi.org/10.3828/extr.2022.11.

Chiles, R. M., G. Broad, M. Gagnon, et al. 2021. "Democratizing Ownership and Participation in the 4th Industrial Revolution: Challenges and Opportunities in Cellular Agriculture." *Agriculture and Human Values* 38, no. 4: 943–961. https://doi.org/10.1007/s10460-021-10237-7.

Chriki, S., and J. F. Hocquette. 2020. "The Myth of Cultured Meat: A Review." *Frontiers in Nutrition* 7, no. February: 1–9. https://doi.org/10.3389/fnut.2020.00007.

Combelles, A., C. Ebert, and P. Lucena. 2020. "Design Thinking." *IEEE Software* 37, no. 2: 21–24.

Dueñas-Ocampo, S., W. Eichhorst, and P. Newton. 2023. "Plant-Based and Cultivated Meat in the United States: A Review and Research Agenda Through the Lens of Socio-Technical Transitions." *Journal of Cleaner Production* 405, no. March: 136999. https://doi.org/10.1016/j.jclepro.2023.136999.

FAO. (2015). The Economic Lives of Smallholder Farmers. *FAO Food And Agriculture Organization of the United Nations*, 39. http://www.macrothink.org/journal/index.php/rae/article/view/6320%0Ahttp://www.upov.int/edocs/mdocs/upov/en/upov_sym_ge_11/upov_sym_ge_11_10.pdf%0Ahttp://ajae.oxfordjournals.org/cgi/doi/10.2307/1241587%0Awww.iosrjournals.org%0Ahttp://link.springer.com/10.

FAO. (2021). Africa – Regional Overview of Food Security and Nutrition 2021. In *Africa – Regional Overview of Food Security and Nutrition 2021*. https://doi.org/10.4060/cb7496en.

FAO. (2022). Food Safety Aspects of Cell-Based Food. *Food Safety Aspects of Cell-Based Food*. https://doi.org/10.4060/cc2353en.

Florian. (2024). The Role of Design in Shaping Sustainable Futures The 14th Design Thinking Research Symposium.

Folke, C., S. Carpenter, T. Elmqvist, L. Gunderson, C. S. Holling, and B. Walker. 2002. "Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations." *AMBIO: A Journal of the Human Environment* 31, no. 5: 437–440. https://doi.org/10.1579/0044-7447-31.5.437.

Francis Gomes, J. B. M., and S. Moqaddermerad. 2015. "Futures Business Models for an Iot Enabled Health Care Sector: From a Causal Layered Perspective." *Journal of Business Models* 4, no. AUGUST: 60–80.

Galanakis, C. M. 2024. "The Future of Food." In *Foods* (13, Issue 4). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/foods13040506.

Gallen, C., G. Pantin-Sohier, and D. Oliveira. 2022. "How Can the Design Thinking Process Improve an Innovative Insect-Based Food Experience?" *International Journal of Food Design* 7, no. 1: 29–58. https://doi.org/10.1386/ijfd_00035_1.

Gasparini, A. A. 2015. "Perspective and Use of Empathy in Design Thinking." *ACHI 2015 - 8th International Conference on Advances in Computer-Human Interactions*, *March*: 49–54. https://personales.upv.es/thinkmind/dl/conferences/achi/achi_2015/achi_2015_3_10_20121.pdf.

Gasteratos, K. (2019). 90 Reasons to Consider Cellular Agriculture. *The Harvard*, Gasteratos, Kristopher. 2019. 90 Reasons to Consid. http://nrs.harvard.edu/urn-3:HUL.InstRepos:38573490.

Glaros, A., R. Newell, E. Fraser, and L. L. Newman. 2023. "Socio-Economic Futures for Cellular Agriculture: The Development of a Novel Framework." *Frontiers in Sustainable Food Systems* 7: 970369. https://doi.org/10.3389/fsufs.2023.970369.

Glenn, J. C. (2004a). Introduction to the Futures Research Methods Series. *Futures Research Methodology - Version 2.0*, 1–61.

Gordon, A., R. Rohrbeck, and J. Schwarz. 2019. "Escaping the 'Faster Horses' Trap: Bridging Strategic Foresight and Design-Based Innovation." *Technology Innovation Management Review* 9, no. 8: 30–42. https://doi.org/10.22215/TIMREVIEW/1259.

Green, H., P. Broun, D. Cook, et al. 2018. "Healthy and Sustainable Diets for Future Generations." *Journal of the Science of Food and Agriculture* 98, no. 9: 3219–3224. https://doi.org/10.1002/jsfa.8953.

Gregor, S., and A. R. Hevner. 2013. "Positioning and Presenting Design Science Research for Maximum Impact." In *MIS Quarterly: Management Information Systems* (37, Issue 2, 337–355. University of Minnesota. https://doi.org/10.25300/MISQ/2013/37.2.01.

Grober, U. (2007). Deep Roots: A Conceptual History of 'Sustainable Development' (Nachhaltigkeit). *WZB Discussion Paper P 2007-002, February*, 1–30.

Hagan, M. 2021. "Introduction to Design Thinking for Law." In *Legal Informatics*, 155–176. Cambridge University Press. https://doi.org/10.1017/9781316529683.015.

Hara, K., R. Yoshioka, M. Kuroda, S. Kurimoto, and T. Saijo. 2019. "Reconciling Intergenerational Conflicts With Imaginary Future Generations: Evidence From a Participatory Deliberation Practice in a Municipality in Japan." *Sustainability Science* 14, no. 6: 1605–1619. https://doi.org/10.1007/s11625-019-00684-x.

Hassi, L., D. Peck, K. Dewulf, and R. Wever. 2009. "Sustainable Innovation – Organisation and Goal Finding." In *Proceedings of Joint Actions on Climate Change*, edited by K. Nielsen, S. B Christensen, and G. Hansen, 1–25. 185-201 Aalborg University, Department of Development and Planning.

Hautamäki, A. 2010. "Book Review: Sustainable Innovation: A New Age of Innovation and Finland's Innovation Policy." In *Human Technology: An Interdisciplinary Journal on Humans in ICT Environments* 6, no. 2: A1. https://doi.org/10.17011/ht/urn.201011173095.

Head, B., and J. Alford (2008). *Wicked Problems: The Implications for Public Management Wicked Problems: The Implications for Public Management Brian Head (University of Queensland) and. June 2014.*

Heinonen, S., J. Karjalainen, J. Ruotsalainen, and K. Steinmüller. 2017. "Surprise as the New Normal – Implications for Energy Security." *European Journal of Futures Research* 5, no. 1: 12. https://doi.org/10.1007/s40309-017-0117-5.

Hibino, A., J. Minari, K. Takahashi, Y. Sugiyama, and S. Kawana. 2024. "The Cultural Construction of Cellular Agriculture Food: Through the Lens of the Whole-Parts Framework for Meat." *Frontiers in Sustainable Food Systems* 8: 1356012. https://doi.org/10.3389/fsufs.2024.1358012.

Hines, A. 2020. "When Did It Start? Origin of the Foresight Field." *World Futures Review* 12, no. 1: 4–11. https://doi.org/10.1177/1946756719889053.

Hocquette, É., J. Liu, M. P. Ellies-Oury, S. Chriki, and J. F. Hocquette. 2022. "Does the Future of Meat in France Depend on Cultured Muscle Cells? Answers From Different Consumer Segments." *Meat Science* 188: 108776. https://doi.org/10.1016/j.meatsci.2022.108776.

Hoyos, D., R. Bermejo, and I. Arto. 2010. "Sustainable Development in the Brundtland Report and Its Distortion: Implications for Development Economics and International Cooperation." In *ResearchGate*, edited by K. Unceta, and A. Arrinda, 13–34. Development cooperation: Facing the challenges of global change.

Hubalek, S., M. J. Post, and P. Moutsatsou. 2022. "Towards Resource-Efficient and Cost-Efficient Cultured Meat." *Current Opinion in Food Science* 47: 100885. https://doi.org/10.1016/j.cofs.2022.100885.

Jensen, M. B., F. Lozano, and M. Steinert. 2016. "The Origins of Design Thinking and the Relevance In Software Innovations." *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* 10027 LNCS, no. November: 675–678. https://doi.org/10.1007/978-3-319-49094-6_54.

Jönsson, E. 2020. "on Breweries and Bioreactors: Probing the "Present Futures" of Cellular Agriculture." *Transactions of the Institute of British Geographers* 45, no. 4: 921–936. https://doi.org/10.1111/tran.12392.

Kagan, S., A. Hauerwaas, S. Helldorff, and U. Weisenfeld. 2020. "Jamming Sustainable Futures: Assessing the Potential of Design Thinking With the Case Study of a Sustainability Jam." *Journal of Cleaner Production* 251: 119595. https://doi.org/10.1016/j.jclepro.2019.119595.

Kelley, D., and T. Brown. 2018. "An Introduction to Design Thinking." In *Design Thinking: A guide to creative problem solving for everyone*, edited by A. Pressman, vol. 6. Iinstitute of Design at Stanford. https://dschool-old.stanford.edu/sandbox/groups/designresources/wiki/36873/attachments/74b3d/ModeGuideBOOTCAMP2010L.pdf.

Kirova, M., F. Montanari, I. Ferreira, et al. (2019). Research for AGRI Committee - Megatrends in the Agri-Food Sector: Global Overview and Possible Policy Response From an EU Perspective.

Kombolo Ngah, M., S. Chriki, M. P. Ellies-Oury, J. Liu, and J. F. Hocquette. 2023. "Consumer Perception of "Artificial Meat" in the Educated Young and Urban Population of Africa." *Frontiers in Nutrition* 10, no. April: 1127655. https://doi.org/10.3389/fnut.2023.1127655.

Kosow, H., and G R. (2008). Methods of Future and Scenario Analysis. Overview, Assessment, and Selection Criteria Methods of Future and Scenario Analysis Overview, Assessment, and Selection Criteria (Issue January).

Kristóf, T., and E. Nováky. 2023. "The Story of Futures Studies: An Interdisciplinary Field Rooted in Social Sciences." In *Social Sciences* (12, Issue 3). MDPI. https://doi.org/10.3390/socsci12030192.

Lambert, L. M., C. Selin, and T. Chermack. 2024. "Futures Empathy for Foresight Research and Practice." *Futures* 163: 103441. https://doi.org/10.1016/j.futures.2024.103441.

Linares-Barbero, C., and I. D. L. Vega. 2024. "The Impact of Strategic Foresight on Innovation: A Systematic Literature Review." In *IEEE Engineering Management Review*. Institute of Electrical and Electronics Engineers Inc. https://doi.org/10.1109/EMR.2024.3454630.

Lindgren, M., and H. Bandhold (2003). Scenario Planning: The Link Between Future and Strategy.

Linturi, R., M. Höyssä, O. Kuusi, and V. Vähämäki. 2022. "Radical Technology Inquirer: A Methodology for Holistic, Transparent and Participatory Technology Foresight." *European Journal of Futures Research* 10, no. 1: 18. https://doi.org/10.1186/s40309-022-00206-6.

Ljungberg, E., and S. Skaljo. (2023). From Idea to Innovation: Exploring the Application of Design Thinking in Product Development.

Løgager, K., Kulsbjerg, C. Løgager, L. Simeone, and G. Mejía (2021). Aalborg Universitet A Foresight-Oriented Service Design Approach To Foster Longer-term Thinking and Sustainable Practices.

May, J. (2017). Food Security and Nutrition: Impure, Complex and Wicked? Food Security SA Working Paper Series No.002. DST-NRF Centre of Excellence in Food Security, South Africa.

Mayer, M., V. Ringler, and S. M. Germany. 2014. "Angela Wilkinson Strategic Foresight Counsellor, OECD France Collaborative Futures: Integrating Foresight With Design in Large Scale Innovation Processes-Seeing and Seeding the Futures of Europe." *Journal of Futures Studies* 18, no. 4: A1.

Moritz, J., R. Mazac, M. H. Uete, N. Räty, H. L. Tuomisto, and T. Ryynänen. 2024a. "Prospects of Justice for Cellular Agriculture: A Just Transition or Reinvesting in Unsustainability?" *Food Ethics* 9, no. 2: 22. https://doi.org/10.1007/s41055-024-00156-8.

Moritz, J., R. Mazac, M. H. Uete, N. Räty, H. L. Tuomisto, and T. Ryynänen. 2024b. "Prospects of Justice for Cellular Agriculture: A Just Transition or Reinvesting in Unsustainability?" *Food Ethics* 9, no. 2: 25. https://doi.org/10.1007/s41055-024-00159-5.

Moritz, J., H. L. Tuomisto, and T. Ryynänen. 2022. "The Transformative Innovation Potential of Cellular Agriculture: Political and Policy Stakeholders' Perceptions of Cultured Meat in Germany." *Journal of Rural Studies* 89, no. October 2021: 54–65. https://doi.org/10.1016/j.jrurstud.2021.11.018.

Mouat, M. J., R. Prince, and M. M. Roche. 2019. "Making Value Out of Ethics: The Emerging Economic Geography of Lab-Grown Meat and Other Animal-Free Food Products." *Economic Geography* 95, no. 2: 136–158. https://doi.org/10.1080/00130095.2018.1508994.

Moyano-Fernández, C. 2023. "The Moral Pitfalls of Cultivated Meat: Complementing Utilitarian Perspective With Eco-Republican Justice Approach." *Journal of Agricultural and Environmental Ethics* 36, no. 1: 23. https://doi.org/10.1007/s10806-022-09896-1.

Nawrocki, T. L., and I. Jonek-Kowalska. 2022. "Is Innovation a Risky Business? A Comparative Analysis in High-Tech and Traditional Industries in Poland." *Journal of Open Innovation: Technology, Market, and Complexity* 8, no. 3: 155. https://doi.org/10.3390/joitmc8030155.

Niina Veflen Olsen. (2014). Systems Dynamics and Innovation in Food Networks. *International Food and Agriculture Management Association*. http://ageconsearch.umn.edu.

Nordlund, E., M. Lille, P. Silventoinen, et al. 2018a. "Plant Cells as Food – A Concept Taking Shape." *Food Research International* 107, no. December 2017: 297–305. https://doi.org/10.1016/j.foodres.2018.02.045.

Nordlund, E., M. Lille, P. Silventoinen, et al. 2018b. "Plant Cells as Food – A Concept Taking Shape." *Food Research International* 107, no. December 2017: 297–305. https://doi.org/10.1016/j.foodres.2018.02.045.

Nyika, J., J. Mackolil, E. Workie, C. Adhav, and S. Ramadas. 2021. "Cellular Agriculture Research Progress and Prospects: Insights From Bibliometric Analysis." *Current Research in Biotechnology* 3: 215–224. https://doi.org/10.1016/j.crbiot.2021.07.001.

OECD. (2019). Strategic Foresight Strategic Foresight for Better Policies. *October*, 1–12. https://www.oecd.org/strategic-foresight/ourwork/Strategic Foresight for Better Policies.pdf.

Paniagua, K. 2019. "Anticipatory Thinking as a Critical Design Skill: About the Design of Tomorrow One-Year Program." *Journal of Futures Studies* 24, no. 1: 91–100. https://doi.org/10.6531/JFS.201909_24(1).0007.

Papanek, V. 1984. *Desgin For The Real World:Human Ecology and Social Change*, 2nd ed. 415. Thames & Hudson.

Parasecoli, F. 2022. "Food Design, Nutrition, and Innovation." *Frontiers in Public Health* 10, no. 8: 8–11. https://doi.org/10.3389/fpubh.2022.1039795.

Persson, B. M. 2024. "Understanding the Origins of Foresight — How It Has Shaped Our Minds and Societies." *Futures & Foresight Science* 6, no. 1: e.170. https://doi.org/10.1002/FFO2.170.

Pickering, J., T. Hickmann, K. Bäckstrand, et al. 2022. "Democratising Sustainability Transformations: Assessing the Transformative Potential of Democratic Practices in Environmental Governance." In *Earth System Governance* (11). Elsevier B.V. https://doi.org/10.1016/j.esg.2021.100131.

Pinter, D. (2013). Applications, Limitations and Effects of Corporate Foresight Methods-Towards an Evaluation Framework for Innovation Management. https://www.researchgate.net/publication/257919677.

Popper, R. 2008a. "How Are Foresight Methods Selected?" *Foresight* 10, no. 6: 62–89. https://doi.org/10.1108/14636680810918586.

Popper, R. 2008b. "How Are Foresight Methods Selected?" *Foresight* 10, no. 6: 62–89. https://doi.org/10.1108/14636680810918586.

Post, M. J. 2012. "Cultured Meat From Stem Cells: Challenges and Prospects." *Meat Science* 92, no. 3: 297–301. https://doi.org/10.1016/j.meatsci.2012.04.008.

Prager, S. D., and K. Wiebe. 2021. "Strategic Foresight for Agriculture: Past Ghosts, Present Challenges, and Future Opportunities." *Global Food Security* 28: 100489. https://doi.org/10.1016/j.gfs.2020.100489.

Puglisi, M. (2001). The Study of the Futures: An Overview of. 463, 439–463.

Räty, N., H. L. Tuomisto, and T. Ryynänen. 2023. "On What Basis Is It Agriculture?" *Technological Forecasting and Social Change* 196: 122797. https://doi.org/10.1016/j.techfore.2023.122797.

Razzouk, R., and V. Shute. 2012. "What Is Design Thinking and Why Is It Important?" *Review of Educational Research* 82, no. 3: 330–348. https://doi.org/10.3102/0034654312457429.

Remington, S. (2013). Wicked Problems and Their Resolution.

Remington-Doucette, and Sonya. 2013. *Sustainable World: Approaches to Analyzing and Resolving Wicked Problems*. Kendall Hunt.

Rischer, H., G. R. Szilvay, and K. M. Oksman-Caldentey. 2020. "Cellular Agriculture — Industrial Biotechnology for Food and Materials." *Current Opinion in Biotechnology* 61: 128–134. https://doi.org/10.1016/j.copbio.2019.12.003.

Rittel, H. W. J., and M. M. Webber. 1973a. "Dilemmas in a General Theory of Planning Published by: Springer." *Policy sciences* 4, no. 2: 155–169.

Rittel, H. W. J., and M. M. Webber. 1973b. "Dilemmas in a General Theory of Planning Published by: Springer." *Policy sciences* 4, no. 2: 155–169.

Rodgers, P., and E. Winton (2014). "Design Thinking" – A Critical Analysis. September 2010.

Rosa, A. B., S. Kimpeler, E. Schirrmeister, and P. Warnke. 2021. "Participatory Foresight and Reflexive Innovation: Setting Policy Goals and Developing Strategies in a Bottom-Up, Mission-Oriented, Sustainable Way." *European Journal of Futures Research* 9, no. 1: 2. https://doi.org/10.1186/s40309-021-00171-6.

Rösch, N., V. Tiberius, and S. Kraus. 2023. "Design Thinking for Innovation: Context Factors, Process, and Outcomes." *European Journal of Innovation Management* 26, no. 7: 160–176. https://doi.org/10.1108/EJIM-03-2022-0164.

Saavoss, M. 2019. "How Might Cellular Agriculture Impact the Livestock, Dairy, and Poultry Industries?" *Choices* 34, no. 1: 1–6.

Salminen, J., M. Mäkimattila, and A. Kallio (2012). Issues in Absorbing Foresight Knowledge For Innovation in SMES. https://www.researchgate.net/publication/235225359.

Sardar, Z. 2010. "Welcome to Postnormal Times." *Futures* 42, no. 5: 435–444. https://doi.org/10.1016/j.futures.2009.11.028.

Schultz, P. W. 2000. "New Environmental Theories: Empathizing With Nature: The Effects of Perspective Taking on Concern for Environmental Issues." *Journal of Social Issues* 56: 391–406.

Schwarz, J. O., B. Wach, and R. Rohrbeck. 2023a. "How to Anchor Design Thinking in the Future: Empirical Evidence on the Usage of Strategic Foresight in Design Thinking Projects." *Futures* 149, no. November 2021: 103137. https://doi.org/10.1016/j.futures.2023.103137.

Schwarz, J. O., B. Wach, and R. Rohrbeck. 2023b. "How to Anchor Design Thinking in the Future: Empirical Evidence on the Usage of Strategic Foresight in Design Thinking Projects." *Futures* 149, no. March: 103137. https://doi.org/10.1016/j.futures.2023.103137.

Sergelidis, D. (2019). Lab Grown Meat: The Future Sustainable Alternative to Meat or a Novel Lab Grown Meat: The Future Sustainable Alternative to Meat or a Novel Functional Food? October. https://doi.org/10.26717/BJSTR.2019.17.002930.

Serrat, O. (2010). Knowledge Solutions Design Thinking A Design for Life. *March*, 1–6. www.rotmandesignworks.ca/business_design.html.

Severo, E. A., M. M. S. Perin, J. C. F. De Guimarães, and E. Taufer. 2020. "The Relationship Between Sustainable Innovation and Product or Service Innovation: A Survey in Companies in Rio Grande do Sul." *Revista de Gestão* 27, no. 4: 319–334. https://doi.org/10.1108/REGE-05-2019-0058.

Sijtsema, S. J., V. Fogliano, and M. Hageman. 2020. "Tool to Support Citizen Participation and Multidisciplinarity in Food Innovation: Circular Food Design." *Frontiers in Sustainable Food Systems* 4. https://doi.org/10.3389/fsufs.2020.582193.

Sjöblom, J. (2024). Strategic Foresight for Innovation.

Sohail Inayatullah. 2013. "Futures Studies: Theories and Methods. There's a Future." *Visions for a Better World., May*: 36–66.

Stelzer, B., S. Kohn, and B. Schembera (2020). The Development of Future Personas for Design Thinking processes. https://www.researchgate.net/publication/377330550.

Stephens, N., and M. Ellis. 2020a. "Cellular Agriculture in the UK: A review." In *Wellcome Open Research* (5). F1000 Research Ltd. https://doi.org/10.12688/wellcomeopenres.15685.1.

Stephens, N., and M. Ellis. 2020b. "Cellular Agriculture in the UK: A Review." In *Wellcome Open Research* (5). F1000 Research Ltd. https://doi.org/10.12688/wellcomeopenres.15685.1.

Störmer, E., L. Bontoux, M. Krzysztofowicz, E. Florescu, A.-K. Bock, and F. Scapolo. 2020. "Foresight – Using Science and Evidence to Anticipate and Shape the Future." In *Science for Policy Handbook*. Elsevier. https://doi.org/10.1016/b978-0-12-822596-7.00012-7.

Studer, J. A., S. R. Daly, S. McKilligan, and C. M. Seifert. 2018. "Evidence of Problem Exploration In Creative Designs." *Artificial Intelligence for Engineering Design, Analysis and Manufacturing* 32, no. 4: 415–430. https://doi.org/10.1017/S0890060418000124.

Taylor, S. P. 2017. "What Is Innovation? A Study of the Definitions, Academic Models and Applicability of Innovation to an Example of Social Housing in England." *Open Journal of Social Sciences* 05, no. 11: 128–146. https://doi.org/10.4236/jss.2017.511010.

Thompson, P. B. (2018). 28. Four Sociotechnical Imaginaries for Future Food Systems. 187–191. https://doi.org/10.3920/978-90-8686-869-8_28.

Thoring, K., and R. M. Müller. 2011. "Understanding Design Thinking: A Process Model Based on Method Engineering." *Proceedings of E and PDE 2011, the 13th International Conference on Engineering and Product Design Education, September* DS 69: 493–498.

Thorsen, M., J. Hill, J. Farber, et al. 2025. "Megatrends and Emerging Issues: Impacts on Food Safety." In *Comprehensive Reviews in Food Science and Food Safety* (24, Issue 3). John Wiley and Sons Inc. https://doi.org/10.1111/1541-4337.70170.

Tidd, J. (2006). A Review of Innovation Models. https://doi.org/10.13140/RG.2.2.30295.57762.

Turturean, C. I., U. Alexandru, and I. Cuza. 2011. "Classifications of Foresight Methods. *The Yearbook of The*." *Gh. Zane" Institute of Economic Researches* 20, no. 2: 113–123.

UNDP, G. C. P. S. E. (2018). Foresight Manual. 50.

Victor, R., and V. Vidal (2014). The Future Workshop: Democratic problem solving. May.

Vikas T N, I., I. Vinay C T, I. Habeeba Amrutha Hegaddathy, Rizwan, and I. Rizwan N Shaikh. 2022. "Design Thinking: A Review Paper." *International Journal of Advanced Research in Science, Communication and Technology* 2, no. 2: 405–412. https://doi.org/10.48175/ijarsct-2893.

Vinnari, M., and P. Tapio (2012). Classification of Futures Research Methods and Concepts.

Visser, W. 2020. "Integrated Innovation: Applying Systems Thinking to Sustainable Innovation and Transformation." *Sustainability (Switzerland)* 12, no. 13: 5247. https://doi.org/10.3390/su12135247.

Wach, B., J. O. Schwarz, and F. von Held. 2024. "Corporate Foresight for the Benefit of Corporates' Innovation Climate." *Futures and Foresight Science* 7: e195. https://doi.org/10.1002/ffo2.195.

Wack, P. (1985). Waters Ahead HBR. *Harvard Business Review, September-October*, 18.

Walker, C., T. Nolen, J. Du, and H. Davis (2019). Applying Design Thinking: 19. https://doi.org/10.1145/3347709.3347775.

Weiss, E. B. 1990. "In Fairness to Future Generations." *Environment: Science and Policy for Sustainable Development* 32, no. 3: 6–31. https://doi.org/10.1080/00139157.1990.9929015.

Wittman, H. 2023. "Food Sovereignty: An Inclusive Model for Feeding the World and Cooling the Planet." In *One Earth* (6, Issue 5, 474–478. Cell Press. https://doi.org/10.1016/j.oneear.2023.04.011.

Zampollo, F., and M. Peacock. 2016. "Food Design Thinking: A Branch of Design Thinking Specific to Food Design." *Journal of Creative Behavior* 50, no. 3: 203–210. https://doi.org/10.1002/jocb.148.