MSc Programme in Urban Management and Development

Rotterdam, the Netherlands

November 2021

Thesis title: Securing the Future: Analysing the Protein Transition in Singapore

Name: Crystal Pay

Supervisor: Dr Alberto Gianoli

Specialisation: Urban Environment, Sustainability and Climate Change

Country: Singapore

Report number: 1515

UMD 17

IHS Making cities work Erasmus

Institute for Housing and Urban Development Studies of Erasmus University Rotterdam

Summary

Production of conventional proteins (including both meat and seafood) contributes significantly to climate change and other environmental and social impacts. Transitioning to a food system based on alternative proteins has thus been globally advocated to alleviate the externalities while feeding the growing world population. However, the transition to alternative proteins is ubiquitous with complexities and challenges. Sustainability transition literature provides critical insights into sustainable pathways, but it tends to focus on European countries and a few key sectors but neglect food systems. To overcome these gaps, an operational approach is developed in this paper to examine the influence of key factors driving and hindering the transition to an alternative protein food system in Singapore. A conceptual framework adapting elements of Multi-Level Perspective (MLP), Technological Innovation System (TIS) and Social Practice Theory (SPT) has been developed. 16 in-depth interviews, 170 consumer surveys and desk research were performed to empirically test this framework.

The results are that landscape factors such as climate change, food security and COVID-19 are exerting pressure on the food production regime, creating opportunities for alternative protein niches to break through. Political actors in Singapore respond favourably through establishing the "30 by 30" goal, which targets to produce 30% of Singapore's food needs locally by 2030 (Lim, 2021). Governmental strategies are targeted at nurturing the niches, protecting them from the selection pressures embedded in the regime. As an agricultural-neutral city-state, local meat producers possess little power to resist. However, governmental strategies exhibit insufficient attention paid to the intersection between regime and consumer practices. Subsequently, regime rules remain largely intact, providing little impetus for local food processing companies or consumers to adopt alternative proteins. Moreover, legitimation bestowed by the political actors is nascent and hence, the strength of the innovation system, whilst demonstrating huge growth potential, is in its infancy stage. Consequently, the niches are underdeveloped to destabilise the regime or close the gaps in the regime created by landscape factors.

Hence, "Transformation" path is currently happening as moderate landscape pressure is occurring at a time when the niches are still underdeveloped with little adjustments observed in the regime (Geels & Schot, 2007). Niches are exhibiting symbiotic relationships with the regime as they are increasingly adopted into the regime (Geels & Schot, 2007). As landscape pressure intensifies and political support strengthens further, more adjustments in the regime may emerge. "Transformation" may thus give way to "Reconfiguration" pathway.

Keywords

Alternative proteins, protein transition, sustainability transition, sustainable food systems, food security

Acknowledgements

First of all, I would like to sincerely thank my parents and family for their unwavering support in my pursuit of further studies and exploration of topics I love. Amidst the COVID-19 chaos, supporting my decision was definitely not easy, as health concerns and not knowing when we would reunite were on the line. I would not have been able to accomplish my Master's without their love and support.

I would also like to express my heartfelt gratitude to my thesis supervisor, Dr Alberto Gianoli, Head of Urban Environment, Sustainability and Climate Change. His invaluable guidance helped me tremendously from the beginning, and I cannot imagine having a better supervisor and mentor.

In addition, I am grateful to my interviewee participants for devoting time out of their busy schedules for the interviews. Never would I be able to complete this paper without their kindness and valuable inputs.

I would also like to thank my friend, Qin Yue, for taking time off her busy schedule to proofread my thesis. A like-minded friend who shares the same values, I am thankful for her who is ever so ready to help a friend in need.

Last but not least, I would like to show my appreciation to my dearest partner, Nils. Enormously inspiring and supportive, I am grateful to him for always encouraging me to pursue what I love and strive for my best. I cannot picture going through this academic rigour without him.

Foreword

The externalities of the food systems, particularly meat production, are not known to many. Many of us consume meat every day with little awareness of its contribution to climate change, zoonotic diseases and social inequalities. It is thus essential that we engender transformative changes in protein production to feed the estimated 9 billion world population. It is all the more essential that younger leaders of tomorrow increasingly come forward to tackle these issues. In my capacity as the Michael Fam Chair Professor and Director of Food Science & Technology Programme with Nanyang Technological University Singapore, I am thrilled to endorse this thesis halfway around the world, brilliantly crafted by a passionate student who aspires to analyse and solve the problems of the food system.

A well-structured and clearly-written thesis, it provides a refreshing yet critical take on the transition to alternative proteins in Singapore while developing mind-provoking insights and ideas often overlooked by others. Rightfully grounded in theory, it also value-adds to the existing body of knowledge, with both theoretical and practical implications. Factors that potentially obstruct the transition or undermine the sustainability potential are diagnosed, delivering critical resources to actors seeking to accelerate the transition in a sustainable fashion. Incremental strategies are often advocated to solve problems in food systems, but this thesis has elucidated the risks of incrementalism.

This paper is exceptionally recommended to stakeholders in the alternative protein or food sector as a whole, including government officials, research and education institutes, start-ups, established companies and non-profit organisations. Stakeholders can benefit from the identified factors that obstruct the transition or undermine the sustainability potential, and thus, strategise to accelerate the transition more effectively and sustainably. Sustainability transitions researchers can also leverage the conceptual framework meticulously developed and tested in this paper, which integrates relevant and prominent transitions frameworks and offers a variety of sound indicators for critical analysis.

William Chen

Dr William Chen

Michael Fam Chair Professor and Director

Food Science & Technology Programme

Nanyang Technological University Singapore

List of Abbreviations

A*STAR	Agency for Science, Technology and Research (Statutory Board under MTI)
AVA	Agri-Food and Veterinary Authority of Singapore (Later renamed and reorganised as Singapore Food Agency (SFA))
BIV	Big Idea Ventures
EDB	Economic Development Board (Statutory Board under MTI)
ESG	Enterprise Singapore (Statutory Board under MTI)
GFI	Good Food Institute
GHGE	Greenhouse Gas Emissions
IPCC	Intergovernmental Panel on Climate Change
MLP	Multi-Level Perspective
MSE	Ministry of Sustainability and Environment
MTI	Ministry of Trade and Industry
R&D	Research and Development
SFA	Singapore Food Agency (Statutory Board under MSE)
SNM	Strategic Niche Management
SPT	Social Practice Theory
STRN	Sustainability Transitions Research Network
TIS	Technological Innovation System
TM	Transition Management

Table of Contents

List of Figures

List of Tables

Chapter 1: Introduction

1.1 Background

Current food systems are a complex web of global problems, spanning from massive greenhouse gas emissions (GHGE), health problems and the emergence of zoonotic diseases. Nourishing the world's growing population based on business-as-usual is beyond planetary boundaries (Food and Agricultural Organisation of the United Nations [FAO], 2017). By 2050, cities will consume over 80% of the food (United Nation Development Programme [UNDP], 2020) produced by food systems that contribute more than one-third of global anthropogenic GHGE (Crippa et al., 2021). 23% of GHGE arise from agriculture, livestock and the land and forests needed to raise the livestock (Intergovernmental Panel on Climate Change [IPCC], 2020). The 2015 Paris Agreement aims to maintain the rise in the global average temperature to below 2°C above pre-industrial levels (United Nations Framework Convention on Climate Change [UNFCCC], 2015). Bajželj et al. (2014) discovered that if no changes are made to the food systems, all other GHGE sources would have to be reduced to almost zero to keep the temperature increase under 2°C. Without decreasing meat and dairy consumption, improving food production yield and reducing food waste alone would not achieve the desired reduction in GHGE (Bajželj et al., 2014).

There is also growing scientific evidence supporting the correlation between animal-based food consumption and adverse health impacts. Animal-based food has been shown to increase the risk of health issues such as Type 2 diabetes, cancer and cardiovascular diseases (Bouvard et al., 2015; Micha et al., 2017; Schwingshackl et al., 2017). Moreover, the COVID-19 pandemic has heightened the need to consider the role of meat and dairy production in transmitting zoonotic diseases (Espinosa et al., 2020). Intensive animal farming, often associated with the genetic and physical proximity of animals in poor health, creates conditions for the emergence of zoonotic diseases (Coker et al., 2011). Given the window of opportunity created by COVID-19, a shift in current food systems is critical to address health risks at the nexus of environment, human and animal (Espinosa et al., 2020). Consuming over 80% of the food by 2050 (UNDP, 2020), cities can take impactful actions. Moving to alternative protein food systems is recommended as a strategy to diminish the environmental impacts of food systems by 46-74% (Harwatt et al., 2017) and decrease GHGE by 80% by 2050 (Willett et al., 2019), whilst reducing the risk of another pandemic caused by zoonotic diseases and curtailing healthcare costs (Ornish et al., 2008).

A repertoire of academic scholars argues for the need for so-called sustainability transitions to transform the existing food regime into an alternative regime constructed upon the notions of sustainable production and consumption (Hinrichs, 2014; Ingram, 2015; Meynard et al., 2017; Gaitán-Cremaschi et al., 2019). The concept of sustainability transitions has also received mounting attention in the policy field (El Bilali, 2019a; Lachman, 2013; Markard et al., 2012). Both the IPCC (2020) and FAO (2019) promote more sustainable diets, including plant-based

protein to reduce greenhouse gas emissions, whilst the European Commission's (EC) Food 2030 Pathways for Action heavily focus on alternative protein and dietary shifts (EC, 2020). Different frameworks have been proposed in sustainability transition literature. Markard et al. (2012), Lachman (2013) and El Bilali (2018) reviewed the more prominent frameworks - Multi-Level Perspective (MLP) (Geels 2002, 2011), Strategic Niche Management (SNM) (Schot & Geels, 2008), Transition Management (TM) (Loorbach 2007, 2010; Rotmans & Loorbach, 2009) and Technological Innovation Systems (TIS) (Bergek et al., 2008). A literature review on these approaches is conducted in Chapter 2, for which a conceptual framework adapting elements of the selected approaches is developed. This conceptual framework forms the basis of this paper.

1.2 Problem statement

Despite its growing relevance, the transition to alternative protein food systems is still ubiquitous with complexities and challenges. The prevalent mentalities dominating diets, cultures and societal infrastructure has built substantial lock-ins and path-dependencies to meat-heavy food systems (Markard & Truffer, 2008). Consequently, this inertia heightens the difficulty of transitioning to alternative protein sources as commitments are required from all actors (Frantzeskaki et al., 2017). Hence, such transitions are still in their early phases, with the revolutionisation of food systems absent from many cities' climate change mitigation strategies (Cleveland, 2020). Transitions literature provides critical insights into sustainable pathways for the economy. These insights have, however, predominantly paid attention to decarbonisation in the energy (36% of the papers), mobility (8%), water and sanitation (7%) sectors (Bergek et al., 2015; Markard et al., 2012; Tziva et al., 2020). Food system transitions are less propelled by technology and have significantly less focus (only 3% of all papers) (Markard et al., 2012). A key reason is that early sustainability transitions research leaned towards "hard" technology solutions (e.g. solar panels, electric vehicles) but the inherent biological character of food systems is less fitting with the technical character of these "hard" technology solutions (Marsden, 2013). Although sustainability transition scholarship has expanded empirically and geographically (El Bilali, 2018) since the Sustainability Transitions Research Network (STRN) published its first research agenda in July 2010 (STRN, 2010), sustainability transitions literature still neglects food systems (El Bilali, 2018). Nevertheless, the gravity and intricacy of challenges confronting food systems imply that this sector warrants more research focus (Audet et al., 2017). Alternative proteins emerge as a crucial solution to this grand challenge (EC, 2020; IPCC, 2020), but the examination of critical forces influencing the transition specific to alternative proteins is substantially lacking.

Given the attention mostly paid to European countries in transitions literature (Markard et al., 2012), efforts to expand the sectoral and geographical focuses of transitions literature via an operational approach seem well-justified. Singapore is chosen for the empirical part of this study, as the shift to alternative proteins aligns with its push in strengthening food security. Singapore currently imports over 90% of its nutritional needs (Singapore Food Agency [SFA], n.d-a), with supply chain disruptions caused by events like COVID-19 threatening Singapore's food security. The aim to produce 30% of the city's food needs locally by 2030 is a national

priority (Lim, 2021). Traditional livestock cultivation is unsuitable due to Singapore's land constraints. In contrast, urban farming and innovative food solutions require little space and are, thus, well-aligned with Singapore's vision to become more self-sufficient in nourishing its population. While there has been some recent literature on the transition to alternative proteins in European countries (e.g. Tziva et al., 2020), the differences in the motivation behind the push may result in distinctive transition pathways and impacts. Hence, this makes Singapore an exciting subject, as the transition is not guided by the intention to reduce externalities associated with a meat-based food system, but rather, by the motivation behind enhancing food security where conventional livestock production is unsuitable.

1.3 Research objective

In response to the lack of operational approaches in transitions literature (Gaitán-Cremaschi et al., 2018), this paper aims to develop an operational approach to carefully examine the influence of key factors driving and hindering the transition to an alternative protein food system in Singapore. Results from this paper will unveil deep insights into the role, position and influence of the involved actors and disclose the mechanisms fostering or hindering the transition towards an alternative protein food system. A broad perspective to the whole process of transition, including identification of its drivers and obstacles, is essential as the scale of the desired transition will be unparalleled in human history and will face resistance in many forms (Friel et al., 2009). Hence, research on food system transformations can be informed, guiding relevant actors and policymakers in their investments and policies to promote desirable transition pathways and counter undesirable prevailing systems (Kivimaa & Kern, 2016).

1.4 Research questions

By applying a framework combining the elements of MLP, TIS and SPT supplemented with Singapore's contextual perspective, this paper aims to answer the primary research question: What is the influence of the key driving and hindering factors on the transition to an alternative protein food system in Singapore?

The insights to this research are expected to facilitate a systemic understanding of sustainability transitions and provide guidance to actors involved in accelerating the transition to a food system based on alternative proteins.

To answer the main research question, the following sub-questions are posed:

- How do the actors involved react to the recent developments in the alternative protein food system?
- How do the main functional dynamics of the alternative protein innovation system influence the transition?
- What are the key drivers and barriers to the transition assessed from the responses to the above sub-questions?
- How do the identified drivers and barriers influence the pathway of the transition?

Chapter 2: Literature review

Due to the complexity and interconnectedness of the wicked problems in our current food systems, incremental changes are inadequate, highlighting the necessity for transformative systemic change (STRN, 2010). Further, sustainability transitions are viewed as a critical, long-term and multi-dimensional approach to transforming the existing food regime into an alternative regime built upon the doctrines of sustainable production and consumption (El Bilali, 2018; Gaitán-Cremaschi et al., 2018; Markard et al., 2012). Geels (2018) postulates that these socio-technical transitions comprise changes in both technological and social contexts, e.g. consumer practices, policies and cultural meanings.

Through a systematic review, Markard et al. (2012), Lachman (2013) and El Bilali (2018) identified four prominent frameworks in sustainability transitions – Multi-Level Perspective (MLP), Transition Management (TM), Technological Innovation Systems (TIS) and Strategic Niche Management (SNM). However, as early research on sustainability transitions predominantly focused on "hard" technology sectors like energy and mobility (Hinrichs, 2014; Markard et al., 2012), these frameworks are correspondingly more suitable for understanding such systems (El Bilali & Probst, 2017). The lack of focus on agency in these frameworks (Genus & Coles, 2008) highlights their inadequacy in catering to the idiosyncrasies of food systems where the social element is particularly distinctive (Vinnari & Vinnari, 2014). Therefore, Geels (2018) underscores that food transition is more than a technology challenge, but is also a social issue that needs to consider diverse actors' views, interests and actions (Jorgensen, 2012). Correspondingly, the utilisation of Social Practice Theory (SPT) has increased recently to explicitly incorporate agency in transitions analysis (El Bilali, 2018).

This section explores these five frameworks (MLP, TM, SNM, TIS and SPT) alongside the integrated perspectives academic scholars have put forth. The end of this chapter draws a conceptual framework adapted from the selected perspectives, which establishes the basis for empirical research in the subsequent chapters.

2.1 Multi-Level Perspective (MLP)

The key idea of MLP is that transitions arise via interactions within and amongst three levels: (a) niches develop internal momentum, (b) landscape changes pressurise the regime, (c) destabilising regime generates opportunities for niches to break through (Geels, 2002, 2010, 2011; Rip & Kemp, 1998; Schot & Geels, 2008; Smith et al., 2005; Smith et al., 2010), as illustrated in Figure 1.

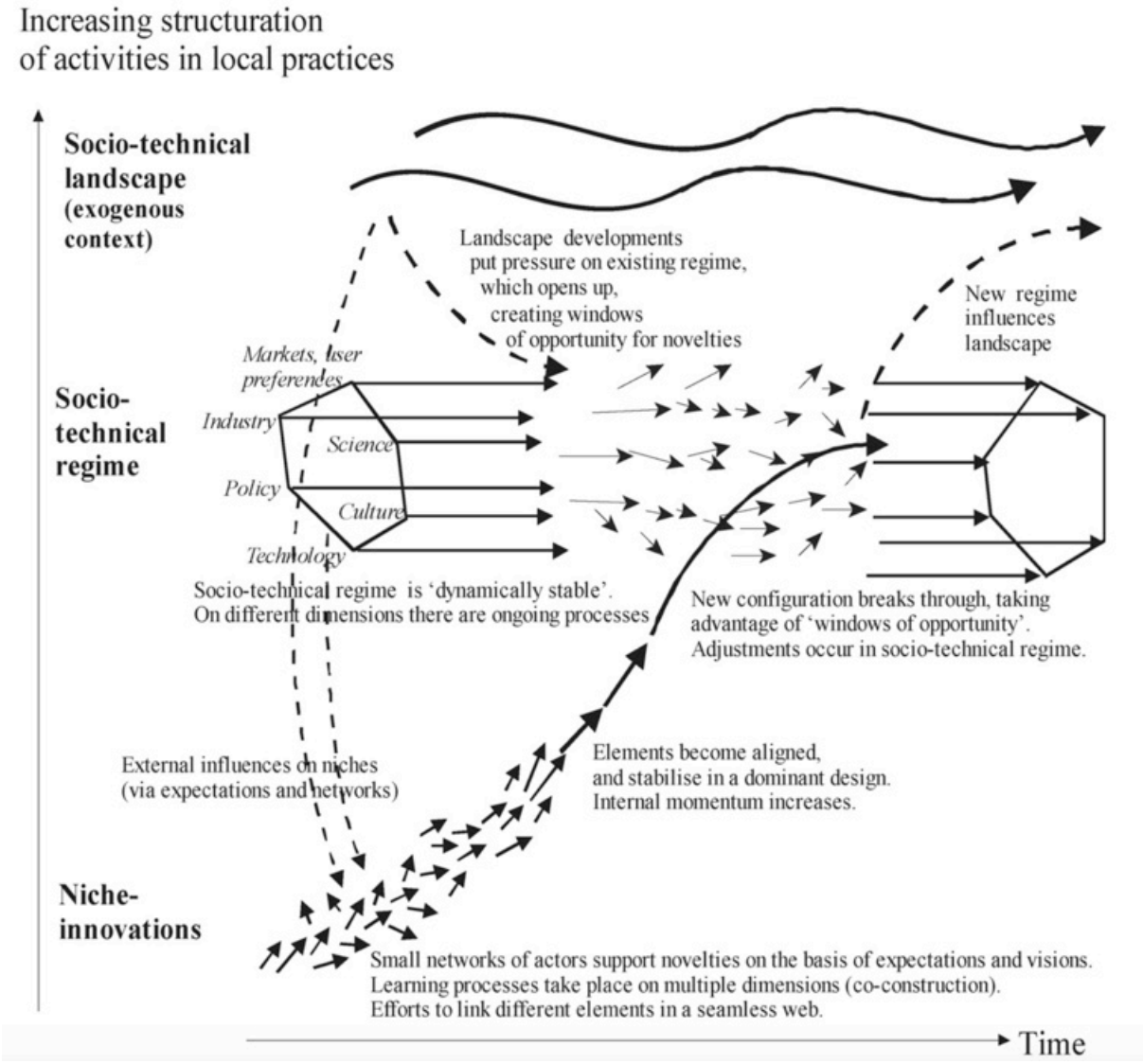


Figure 1: Multi-level perspective on transitions

(From Geels, 2002, p.1263)

Socio-technical regimes refer to the formations of incumbent actors and technologies and their accompanying rules (Geels & Schot, 2007). Further, Järnberg et al. (2018, p.412) assert that incumbent actors include "key governmental actors and their associated institutional structures in the agri-food sector, dominant practices and the associated patterns of ecosystem services and human well-being". The incumbent urban food system can be conceptualised as the socio-technical regime, where different system components interact and collectively offer food services for the society (Markard et al., 2012). The systems concept accentuates the interdependency of its components which has a critical impact on the system dynamics and transformation (Markard et al., 2012). The regime can face pressure from the overarching landscape such as climate change, dietary shifts, population growth and supply chain shocks and crises (Kuokkanen et al., 2018; Lachman, 2013), thus creating openings in the regime for niches to leverage (Smith et al., 2010). In contrast, niches, where innovation activities occur,

are spaces shielded from the dominant regime, thus offering alternative ways of fulfilling the same need (Geels, 2011; Kuokkanen et al., 2018; Smith et al., 2010). For example, novel products like cultivated meat offer similar taste and texture to meat but promise reduced externalities.

The configurations of actors, institutional structures and dominant practices (Järnberg et al., 2018) account for the lock-in of various societal areas (Geels & Schot, 2007), such as food production, distribution and consumption (Audet et al., 2017). The regime is regulated through different rules: cognitive, regulative and normative rules (Audet et al., 2017). These rules reinforce the lock-ins, thus imposing selection pressures that impede the niches' success to stabilise the regime configuration (Audet et al., 2017). Hence, the regime generally strives to uphold its dominance by favouring incremental changes to solve problems in the regime (Ingram, 2015) and by obstructing radical niches that threaten the regime (Ingram, 2015; Meynard et al., 2017). Key actors may put forth linking mechanisms which enable the cross-fertilisation between both levels and thus lead to system reconfiguration (El Bilali et al., 2019b). Elzen et al. (2012, as cited in Bui et al. (2016, p.101)) propose three types of successful linking mechanisms which strengthen the connections between the niches and regime:

- "Network anchoring (expansion of the network of actors supporting the niches and the intensification of contacts, exchanges and interdependencies among these actors);
- Institutional anchoring (translation of rules built inside niches into formal and informal regime rules); and
- Technological anchoring (specification of technical attributes of novelty)."

Recognising that niches may add to or disrupt the regime and considering the timing of interactions, Geels and Schot (2007, p.406) put forth a taxonomy of transition pathways: "transformation, reconfiguration, technological substitution, and de-alignment and re-alignment". Such transition pathways may be driven by niche actors and regime actors capable of enabling the changes (Ingram, 2015; Smith & Raven, 2012). As a result, hybrid food systems comprising innovations produced by both the regime and niches may exist (Gaitán-Cremaschi et al., 2018). Such systems, which often require the regime actors to be open-minded to niche innovations (Darnhofer et al., 2015), perform at the intersections of the regime and niches (Lamine et al., 2012; Plumecocq et al., 2018).

As mentioned, actors and agency play a key role in sustainability transitions, and a lack of understanding may undermine the success of the transition. While the MLP has demonstrated to be a valuable heuristic (El Bilali & Probst, 2017; Genus & Coles, 2008), it has been criticised for its lack of operationalisation, lack of conceptualisation of agency and partiality towards bottom-up change models (Berkhout et al., 2004; El Bilali, 2018; Smith et al., 2005). While Geels (2011, p.29) disputes that MLP is "shot through with agency, because the trajectories and multi-level alignments are always enacted by social groups", Seyfang & Smith (2007) stress that MLP-based research typically emphasise actors and agency in the incumbent regime in influencing transition processes, but neglect civil society actors. Thus, the analysis of civil society actors, i.e. consumers, is discussed under Chapter 2.5 Social Practice Theory (SPT).

2.2 Technological Innovation Systems (TIS)

At the niche level in MLP, TIS is often used as a framework to assess the functional dynamics of the technological innovation system (Markard & Truffer, 2008) as technological innovations opposing the incumbent socio-technical system arise. A TIS is a network of institutions and actors interacting in a specific technological field to promote technological innovations (Bergek et al., 2008; Carlsson & Stankiewicz, 1991; Markard & Truffer, 2008). The main objective of the TIS approach is to analyse all activities instrumental in developing, diffusing and utilising technological innovations (El Bilali, 2018). A TIS may comprise various niches (alternative protein innovations) alongside niche actors, networks and institutions (Markard & Truffer, 2008).

Like MLP, TIS has also been criticised for its lack of operationalisation (El Bilali & Probst, 2017), hence not providing sufficient practical guidelines to policymakers (Edquist, 2004; Klein Woolthuis et al., 2005). Bergek et al. (2008) thus developed a prescriptive TIS framework that outlines six steps, starting from identifying the TIS and its structural components, as illustrated in Figure 2.

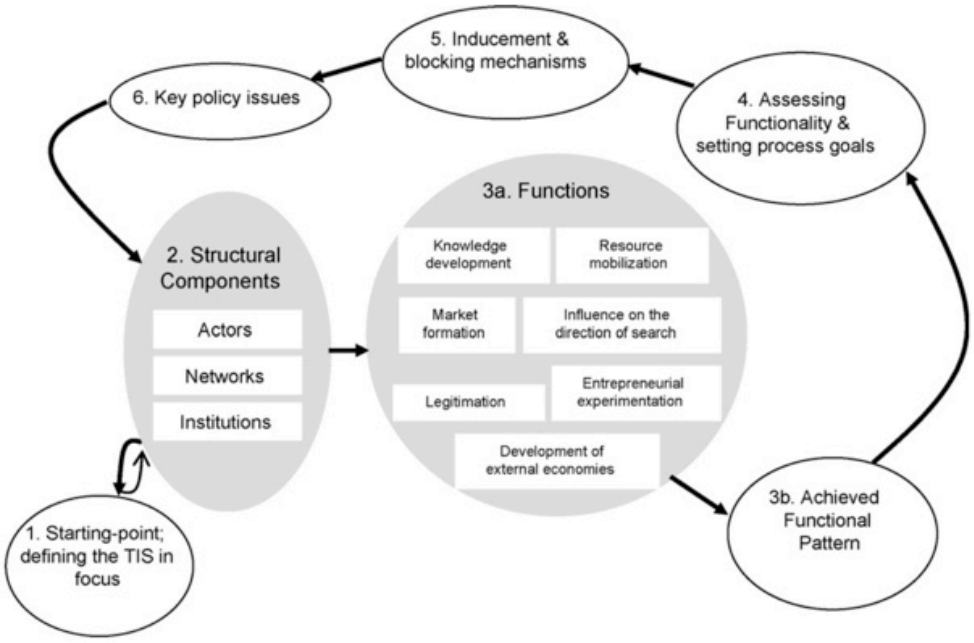


Figure 2: Scheme of Analysis of TIS

(From Oltander and Perez Vico, 2005, as cited in Bergek et al., 2008, p.411)

The highlight of Bergek et al. (2008)'s framework is the seven essential functions to assess the strength of the TIS in breaking through the regime when opportunities arise. These seven functions include knowledge development, resource mobilisation, market formation, influence on the direction of search, legitimation, entrepreneurial experimentation and development of external economies (Bergek et al., 2008). Indicators have been suggested for each function, thus responding to the criticism on the lack of operationalisation in TIS theory.

The main application of a TIS approach is a systemic identification of the blocking mechanisms and weaknesses in a system's networks, institutions and infrastructure (Jacobsson and Bergek, 2011). This means that TIS helps guide policies to overcome the identified blocking mechanism and weaknesses. Nonetheless, as TIS is criticised for being inward-looking without sufficiently considering the environment (Markard & Truffer, 2008), its theory should not be used in isolation.

2.3 Transition Management (TM)

Transition Management (TM) is defined as the intentional restructuring of the socio-technical regime towards a more sustainable state (Vinnari & Vinnari, 2014). It emphasises creating alternative visions to influence regime actors (Kemp et al., 2007; Loorbach, 2007; Rotmans et al., 2001; Schot & Geels, 2008). Rotmans et al. (2001) highlight three crucial elements for successful TM – (1) long-term perspective for formulating short-term policy, (2) focus on learning and (3) keeping options open. Creating such visions fosters long-term thinking, critical for developing shorter-term policies that are multi-domain, multi-level and multi-actor (Rotmans et al., 2001). Locked-in onto prematurely-selected options can be prevented by keeping options open (Rotmans et al., 2001). The focus on first- and second-order learning through experimentation and social learning is reinforced by other academic scholars (Beers et al., 2014; Kemp & Loorbach, 2005; Wals, 2007). Nonetheless, Beers et al. (2014) argue that the TM literature inadequately elaborates the learning processes involved in transition experiments and journeys.

Although TM is similar to SNM in focusing on critical processes to develop niches (El Bilali, 2018), TM advocates also argue for a governmental focus on exerting pressure on the existing regime to allow niches to break through successfully (Kern & Smith, 2008). Policy instruments like taxes on the regime to construct a "level playing field" between the regime and niches are thus recommended (Kemp & Rotmans, 2004, p.152). In view of the need to exercise greater governmental activities over the process, Loorbach (2010) developed a four-phase transition management cycle involving strategic, tactical, operational and reflexive governance action. While it has been criticised for the lack of specification and operationalisation (Vinnari & Vinnari, 2014), it is a helpful heuristic to identify the essential governance activities to transform the political decision-making landscape so that sustainable choices are enabled (Vinnari & Vinnari, 2014). Therefore, while a key criticism of TM is that transitions cannot be managed (Walker & Shove 2007), the primary role of politics cannot be neglected (Meadowcroft 2012; Voß et al., 2009). By creating a "level playing field" between the regime and niche actors (Kemp & Rotmans, 2004, p.152), political actions frame the setting within which individuals make their consumption decisions, thus determining if sustainable consumption can be achieved (Vinnari & Vinnari, 2014).

As a transitions governance framework founded upon complexity theory (Rotmans et al., 2001; Rotmans & Loorbach, 2009), TM is frequently criticised as facilitating incrementalism (Frantzeskaki et al., 2012; Shove & Walker, 2007). Although the notion of incrementalism is highlighted by Rotmans et al. (2001) and Kern and Smith (2008) as an advantage since it

achieves gradual structural change and refrains from excessive destruction of the existing regime thus avoiding societal resistance, Frantzeskaki et al. (2018) and STRN (2010) dispute that marginal changes are ineffective given the wicked problems entrenched in the structure of the socio-technical system.

2.4 Strategic Niche Management (SNM)

SNM refers to the governance and management of internal niche dynamics and, like TM, arose from the desire to encourage niche innovation and regime transformation (El Bilali, 2018). Hence, SNM supports the reflexive management of niches to enable niches to break through the regime (Schot & Geels, 2008).

Like TM, SNM considers building social networks and learning at multiple levels (first and second-order learning) vital in successful niche development (El Bilali, 2018; Schot & Geels, 2008). Additionally, articulating visions and expectations is critical as it directs and legitimates niche development and protection (El Bilali, 2018). This is evident by how visions, learning and networks about biofuels have been shaped in the sustainability direction over time (Raman and Mohr, 2014).

While it is crucial to construct the impetus for niches to break through, the weakness of SNM, similar to TIS, lies in its inward-looking approach towards niche development with marginal attention to external processes occurring in the landscape or regime (Smith, 2007). Niches are viewed as crucial in enabling regime shifts, but niches alone are likely unable to transform regimes (Smith, 2007). In practice, success is most likely when robust niches are in tune with the regime but such compatibility will not adequately transform regimes (Smith, 2007). In contrast, radical niches demanding too many structural changes may fail to break through a regime (Smith, 2007). Too much focus on niches can also inadvertently reinforce lock-ins and the regime, diverting actions away from regime transformation (Geels, 2014; Kuokkanen et al., 2018). Therefore, understanding processes external of the niches on top of a destabilising regime is vital. In this respect, SNM can be viewed as a valuable addition to other frameworks or policy instruments and not be used in isolation (Geels, 2014; Schot & Geels, 2008).

2.5 Social Practice Theory (SPT)

As mentioned earlier, a food transition is more than a technology challenge, but also a social issue that needs to consider diverse actors' views, interests and actions, including consumers' choices (Jorgensen, 2012). The mere focus on upscaling alternative proteins in niches through SNM and TIS, setting long-term visions in TM or understanding interactions amongst the niche-regime-landscape levels is insufficient in enabling transition if consumers are neglected. Nonetheless, the limited available studies operationalising concepts of sustainable food systems tend to ignore the place-based dynamics that characterise food systems and determine the incorporation of sustainable diets, including alternative protein diets (Cifuentes et al., 2021).

The inherent biological characteristic of urban food systems connected to everyday choices means that consumers play a pivotal role in food system shifts. However, its long supply chain underpins the detachment between food provenance and urban consumers. While many advocate education to motivate sustainable food choices, the associations between food knowledge and consumption habits are far too complex (Cifuentes et al., 2021). Research has long demonstrated that food choices are outcomes of the interaction amongst a repertoire of factors such as politics, tradition, culture, socio-economic statuses, health, accessibility and social norms and images (Chen and Antonelli, 2020). Influencing consumers to alter their behaviours by educating or persuading personal values is usually unsuccessful since everyday practices comprise difficult-to-change regimens (Gernert et al., 2018).

As such, Social Practice Theory (SPT), which connects social practices and socio-technical systems (Hargreaves et al., 2011; Moore, 2015), is critical in food sustainability transitions, especially since there have been appeals for more focus on demand and consumption at the consumers' level (Schot & Geels, 2008). Using SPT to understand the routinised behaviours of consumers (Reckwitz, 2002) that determine their consumption choices would therefore offer a response to Gernert et al. (2018)'s argument over the ineffectiveness of education or influencing of personal values given the routine in everyday practices. Social practices comprise "images" (perceptions), "skills" (know-how) and "materials" (artefacts) (Shove & Pantzar, 2005, as cited in Hargreaves et al., 2013, p.405). A key ingredient in enabling sustainability transitions is to analyse these elements and strategise to shift these elements in a more sustainable configuration consistent with the goals of the transition, as noted from the case studies presented in Hargreaves et al. (2013). The uptake of alternative proteins will inevitably vary between different actors and communities due to different practices, socio-economic statuses and priorities (Cifuentes et al., 2021). Therefore, it is critical to identify overlapping practices of different actor groups and amass localised insights about the food system in question to develop a sustainable food strategy that considers the economic, social and cultural context (Campbell, 2004).

In short, SPT overcomes the main criticism relating to lack of agency in other transition frameworks like MLP by combining agency and social constructs to enable sustainable consumption (Liu et al., 2016). Understanding the societal values linked to food consumption is critical in identifying the governance activities to transform the political landscape such that sustainable consumption decisions are empowered (Vinnari & Vinnari, 2014). Nonetheless, as Hargreaves et al. (2013) emphasise in their empirical case studies, SPT is insufficient to be used alone. Efforts to reconfigure social practices may be exasperated by the obstinacy of existing system (Hargreaves et al., 2013). The reverse may also be true as modifications in systems may reconfigure practices (Hargreaves et al., 2013).

2.6 Integration of frameworks and a response to the criticism

To facilitate understanding of the frameworks discussed earlier, a comparison of the five frameworks is illustrated in Figure 3, with a detailed description in Table 1.

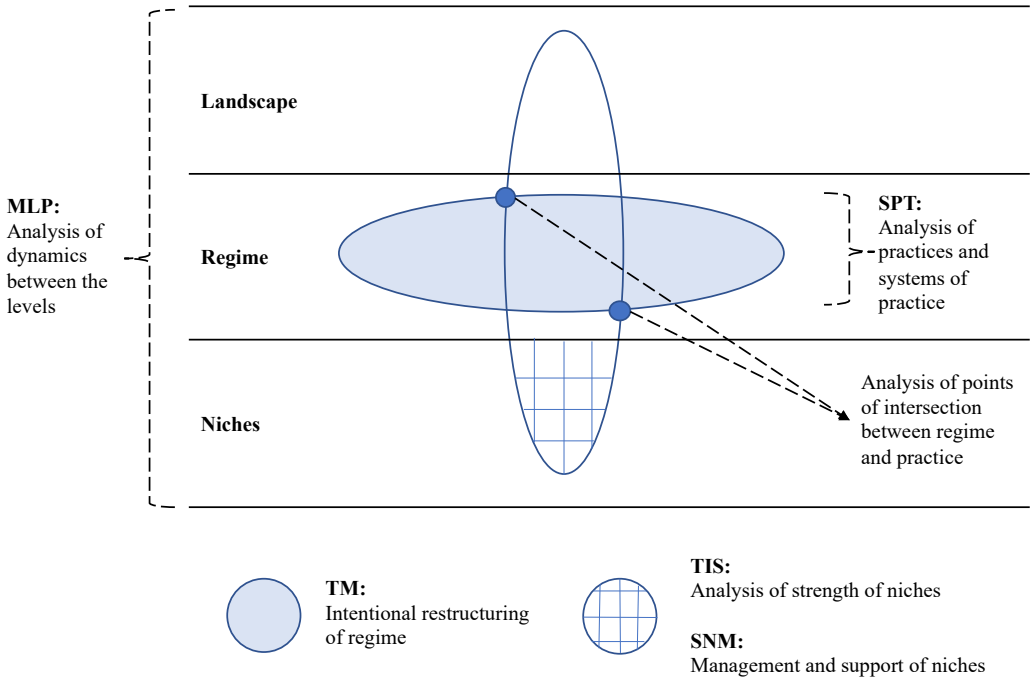


Figure 3: Comparison of the five frameworks

(Adapted from Shove 2003, p.193 cited in Hargreaves et al., 2013, with the addition of TM, TIS and SNM frameworks)

There are three general levels in Figure 3: landscape, regime and niches as defined in the MLP theory (Geels, 2002, 2010, 2011; Rip & Kemp, 1998; Schot & Geels, 2008; Smith et al., 2005; Smith et al., 2010). These are the three levels that establish the foundation of the other theories, of which each theory tends to analyse either one or a combination of a few level(s). TM analyses the sphere exclusive to the regime and enables actors to develop strategies to restructure the regime intentionally, favouring the transition (Vinnari & Vinnari, 2014). On the other hand, SPT is a valuable theory to analyse social practices, which reinforce and, simultaneously, are reinforced by the regime (Hargreaves et al., 2013). TIS and SNM tend to be more exclusive to the niche level, where TIS is used to analyse the strength of niches (Markard & Truffer, 2008), and SNM is usually used to develop strategies to manage and nurture niches tactically (Schot & Geels, 2008).

Table 1: Comparison of the five frameworks

	Multi-level Perspective (MLP)	Technological Innovation System (TIS)	Transition Management (TM)	Strategic Niche Management (SNM)	Social Practice Theory (SPT)
Main objective	Assesses the three levels (landscape, regime and niches) and the interactions amongst the levels	Analyses the actions instrumental in developing and diffusing technological innovations	Develops a strategy that enables the intentional restructuring of the socio-technical regime towards a more sustainable state	Governs, manages and supports niche innovation	Explicitly incorporates agency in the transition analysis
Key elements/ idea	Key idea of MLP is that landscape factors exert pressure on the regime, generating opportunities for niches to break through.	Bergek et al. (2008)'s framework highlights seven key functions to assess the strength of the TIS in breaking through the regime when opportunities arise. Framework also identifies blocking mechanism in the transition.	TM comprises three elements: long-term perspective, learning and openness. Similar to SNM, it emphasises the nurturing of niches but possesses a stronger focus on governance.	SNM comprises three elements: building social networks, learning and articulating expectations and visions.	SPT analyses the configurations of "images", "skill" and "materials" in consumers practices. It is useful for developing strategies to shift the elements into a configuration consistent with the goals of the socio-technical transitions.
Main criticism	Lack of operationalisation and focus on agency	Inward-looking; fail to pay attention to broader system and environment	Advocates incrementalism and transition cannot be managed	Inward-looking; fail to pay attention to broader system and environment	Insufficient to be analysed in isolation; needs to attend to the intersection points between the regime and practices
Literature	El Bilali (2018); Geels, 2002, 2010, 2011; Rip & Kemp, 1998; Seyfang & Smith (2007); Schot & Geels, 2008; Smith et al., 2005; Smith et al., 2010	Bergek et al. (2008); El Bilali (2018); Markard & Truffer (2008)	Rotmans et al. (2001); El Bilali (2018); Frantzeskaki et al. (2012); Kern & Smith (2008); Shove & Walker (2007); Vinnari & Vinnari (2014; Walker and Shove (2007)	El Bilali (2018); Schot & Geels (2008); Smith (2007)	Hargreaves et al. (2013); Shove & Pantzar (2005)

As seen in Table 1, each framework has its shortcomings and is inadequate to use in isolation. Therefore, many academic scholars suggest the integration of frameworks to overcome the shortcomings, for example, the integration of TIS and MLP by Markard and Truffer (2008) and the integration of SPT and MLP by Hinrichs (2014). El Bilali and Probst (2017) propose integrating all five frameworks, starting with mapping the transition dynamics in food systems according to the MLP levels – niche, regime and landscape. As the MLP has been criticised for its lack of operationalisation, the three MLP levers are further operationalised using TM, SNM, TIS and SPT (El Bilali & Probst, 2017).

While El Bilali and Probst (2017)'s integrated framework appears the most complete with an attempt to cater to the idiosyncrasies of food systems, the inclusion of all the prominent concepts has many overlaps. For example, the three crucial processes to SNM put forth by Schot and Geels (2008) (i.e. learning, networking and articulation of visions) overlap with the functions presented in Bergek et al. (2008)'s TIS framework (e.g. knowledge development, entrepreneurial experimentation, influence on the direction of search, legitimation). While TM has its strengths, the framework proposed by academic scholars (notably Loorbach (2010)) appears to be more suitable for frontrunners attempting to develop an ex-ante strategy rather than be used as an analysis of the current transition process.

On the other hand, MLP indeed provides a good starting point to map the transition dynamics of the food system. TIS also supports the analysis of the rise of new technologies (Bergek et al., 2008; Hekkert et al., 2007), whereby the TIS framework presented by Bergek et al. (2008) is a valuable tool for operationalisation as it enables one to understand if the niches have built sufficient momentum, from which blocking mechanisms can be identified. Lastly, a link to SPT completes the picture by reinforcing the analysis of agency – a critical element in food systems. Hence, the conceptual framework used for this paper will combine these frameworks – MLP, TIS and SPT, as seen in Figure 4:

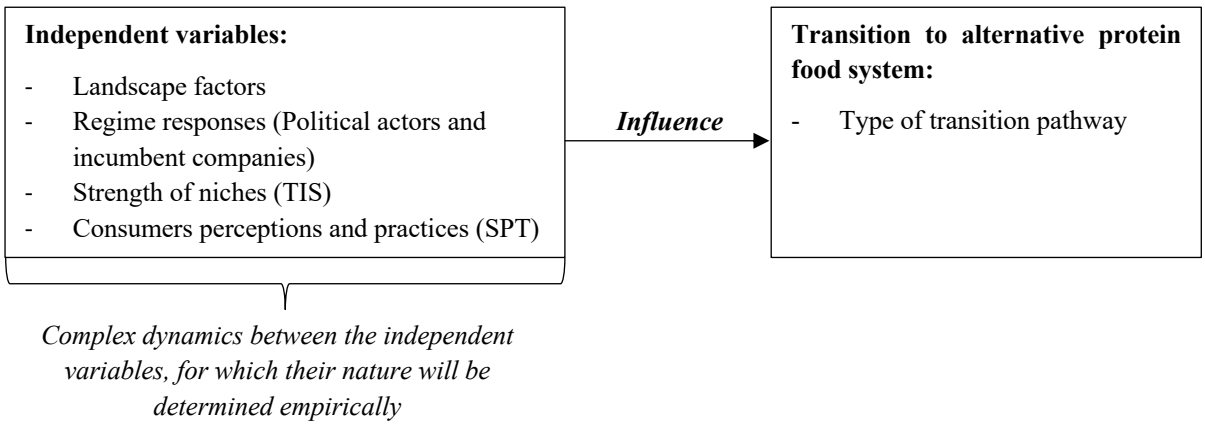


Figure 4: Conceptual framework

MLP is first used as a starting point to map the transition dynamics of the food system according to the levels – landscape, regime and niches. Each level is further operationalised:

i. Landscape

External factors, trends and changes exerting pressure or creating opportunities in food systems must be analysed on top of an understanding of the interactions of these factors and their linkages "through reinforcing feedback loops" (El Bilali & Probst, 2017, p.28).

ii. Regime

At the regime level, actors, networks and institutions (including formal and informal rules) must be analysed (Geels, 2004). The regulative, normative and cognitive components of institutional rules are distinguished by El Bilali and Probst (2017), as defined in Table 2:

Table 2: Types and examples of regime rules

Type	Examples
Regulative	Laws, protocols, standards, formal rules
Normative	Values, norms, expectations
Cognitive	Guiding principles on problem definition

iii. Niches

Using Bergek et al. (2008)'s TIS framework, the TIS and its structural components are first identified. The following steps – mapping and assessing the functional dynamics of the TIS are instrumental in assessing the strength of niches in breaking through the regime. Bergek et al. (2008)'s framework also enables the identification of blocking mechanisms, which is critical to guiding policy action in enabling the transition.

iv. Consumers

Seyfang and Smith (2007) assert that MLP underscores the actors and agency in the incumbent regime in influencing transition processes but neglect civil society actors. Therefore, the actors within civil society settings, i.e. the consumers, are added in this research. Understanding the "images", "skills" and "materials" (Shove & Pantzar, 2005) of consumers' social practices helps to identify the key strategies required to shift these elements of the primary consumers in a more sustainable configuration consistent with the goals of the transition.

Dependent variable – Transition to alternative protein food system

Assessing the independent variables above helps to identify the influence of the driving and hindering forces on the transition. Consequently, the pathway of the transition can be identified using Geels and Schot (2007)'s typology of transition pathways. Understanding these impacts and outcomes helps guide policymakers and other key actors to identify the activities needed to accelerate the transition further.

Chapter 3: Research design, methods and limitations

3.1 Research design

The paper aims to examine the factors that drive or hinder the transition to an alternative protein food system in Singapore. Following Yin (2014), a single, qualitative case study is chosen as a research strategy to gather in-depth knowledge of the developments in the alternative protein food system within Singapore over five years. A longer period, such as ten years and above, would have been chosen for this research. However, preliminary desk research revealed that most of the developments in the alternative protein scene occurred in the last five years, particularly in 2019/2020 when the COVID-19 pandemic began. Nonetheless, expectations and beliefs relating to the next ten years were sought from the interviewees, thus elongating the research period to 15 years in total. A food system based on alternative proteins is a shift away from conventional proteins and to alternative protein sources, including plant-based and fermented ingredients, cellular agriculture and insect protein. This continuum includes plant-based and fungi-based proteins, cellular agriculture, fermentation, insect proteins, as shown in Table 3. On the other hand, conventional proteins include meat and seafood produced by conventional agricultural practices.

Table 3: Taxonomy of alternative proteins included in the research

Plant-based and Fungi-based (both whole-foods and processed)	Cellular Agriculture	Fermentation-based	Insect Protein
- Vegetables - Fruits (e.g. Jackfruit) - Nuts and Seeds - Grains (e.g. Seitan) - Mycoprotein/Fungus - Legumes and Pulses - Tofu/Soybeans - Industry by-products (e.g. Okara from the production of soybean products) - Aquatic plants (e.g. seaweed, micro-algae, alga spirulina)	- Cultivated protein including cultivated meat and seafood	- Alternative protein sources derived from biotransformation processes	- Insect protein (e.g. from Crickets)

(Adapted from World Economic Forum [WEF], 2019 and Enterprise Singapore & Foodvalley NL, 2020)

While transitions, typified by nonlinearity and dynamic interdependencies, involve structural changes in the incumbent socio-technical system (i.e. the food system in this case), this case study seeks to analyse actors' views, motivations, interactions and responses. The strategy employed in this paper follows a deductive research format to trace the developments in the alternative protein food system, identify patterns and interactions while investigating the applicability of the conceptual framework. To illustrate this further, the research comprised six phases, as detailed in Table 4.

Table 4: Outline of research phases

Phase	Description	Data collection method
1. Identify the alternative protein food system	Identify actors, networks and institutions according to the levels in the MLP and delineate system boundaries	Desk research
2. Identify landscape factors and regime responses	Identify exogenous factors that affect the transition via influencing the actors' perspectives and actions, including that of the political actors and incumbent companies	Desk research and in-depth interviews
3. Assess functional dynamics of TIS	Assess the strength of TIS (i.e. the alternative protein innovation system), and how the findings from phase 2 influence it	Desk research and in-depth interviews
4. Assess consumers' perceptions and practices	Assess "images", "skills" and "materials" of consumers (Shove & Pantzar, 2005) with regards to alternative proteins	Desk research and surveys
5. Identify key drivers and barriers	Based on results from phases 2-4, identify key drivers and barriers	Synthesising information from phases 2-4
6. Assess transition pathway	Based on results from phase 5, assess the influence of the driving and hindering factors on the transition pathway	Synthesising information from phase 5

The first phase of this research involved identifying the alternative protein food system and the relevant actors, networks and institutions according to the levels of MLP (Geels, 2002). Food systems are usually linked to regimes external of their apparent boundary (e.g. energy, tourism and health sectors), making the delineation of boundaries challenging (Gaitán-Cremaschi et al., 2018). Nonetheless, for this research, the boundary surrounding the alternative protein food system was set, and factors relating to other socio-technical regimes that may impact the transition (e.g. health) are considered exogenous factors at the landscape level of the MLP.

In the second to fourth phases, exogenous factors including, but not limited to, factors relating to other socio-technical regimes that affect the transition were identified. The impacts and influence of the factors on actors' perspectives and responses, including that of the regime and political actors, niche entrepreneurs and consumers, were assessed. The functional dynamics of the technological innovation system (TIS) were also examined to investigate its strength in breaking through the regime and accelerating the transition. The TIS, in this case, is the alternative protein innovation system comprising niche entrepreneurs. The "images", "skills" and "materials" of consumers (Shove & Pantzar, 2005) regarding alternative proteins vis-à-vis conventional proteins were analysed in the fourth phase.

Tziva et al. (2020) adopted a methodology to analyse the plant-based meat transition in the Netherlands that is highly relevant to this paper. Their research methodology began from secondary data collection, followed by structural analysis and finally, semi-structured in-depth interviews to deeper their understanding of the innovation dynamics occurring in the transition (Tziva et al., 2020). Similarly, for the first to fourth phases, a qualitative event analysis within the years 2017 to 2021 was conducted. Data for analysis of the events was obtained from Lexis Nexis and other online sources such as firms' websites, policy documents and research reports. Lexis Nexis is an information platform that obtains from physical and electronic news sources nationally and internationally. Its accuracy has been proven in other research (Negro &

Hekkert, 2008; Suurs & Hekkert, 2009). Predefined keywords were used to identify relevant secondary data, including alternative proteins, plant-based proteins, meat substitutes, meat analogues, protein innovation and protein transition. Then, selected leads were followed up by including names of particular events, networks, actors and policies. Relevant events instrumental to the growth of the alternative protein sector were chronologically organised, thus enabling the narrative re-construction of the development of the sector in Singapore.

In the fifth to sixth phases, results from phases two to four were used to assess the driving and hindering factors, including their influence on the pathway of the transition.

3.2 Data collection methods

Following the event-history analysis, 16 semi-structured in-depth interviews with relevant actors, including governmental agencies, research and education institutions, niche entrepreneurs, accelerators and non-profit organisations, were conducted. Purposive sampling was employed to reach the right breadth of interviewees such that they represent different sectors and alternative protein streams. Through influential actors, snowball sampling had also been utilised to broaden the audience reach, thus enabling a nuanced and comprehensive assessment of the transition. Below is a nomenclature of the 16 interviewees based on the role they play in the alternative protein value chain:

- **Accelerators:** Three interviews were conducted with three different actors. These accelerators (R1, R2, R16) work with niche entrepreneurs and help them access resources as required. Hence, they often have a broad perspective of the overall transition, which is valuable to the research.
- **Education institutes:** Two interviews were conducted with two different actors (R3, R8), with R8 sharing insights from both of his roles in the education institute and as a niche entrepreneur.
- **Governmental agencies and research institutes:** Three interviews were conducted with three different actors (R4, R12, R13), with two actors sharing insights from their roles at a public-sector research institute.
- **Niche Entrepreneurs:** Eight interviews were conducted with eight entrepreneurs, spanning across the different alternative protein categories and roles in the value chain
    - Plant-based (R5, R9)
    - Fermentation-based (R6, R10)
    - Cultivated (R8, R11)
    - Insect-based (R7)
    - Alternative protein manufacturing company (R15)
- **Non-Profit Organisation:** One interview was conducted with a non-profit organisation (R14) whose work is primarily focused on accelerating the protein transition. Therefore, this organisation has a broad perspective of the overall transition, including the key drivers and barriers.

In the fourth phase, surveys with consumers were conducted. After filtering out 13 incomplete responses, 170 completed surveys were returned. Surveys were chosen over interviews to reach a wider group of consumers and obtain a more representative data set. As a convenience sampling method was engaged for this survey, the sampled population skewed towards participants aged 21-40 years old with a tertiary education level. However, it is worth highlighting that these demographics are most likely to interact with, trial and procure alternative proteins once they are more widely accessible in the market. Nonetheless, the range of dietary preferences of the survey participants is congruent with another survey conducted by Statista as of February 2020, as seen in Figure 5:

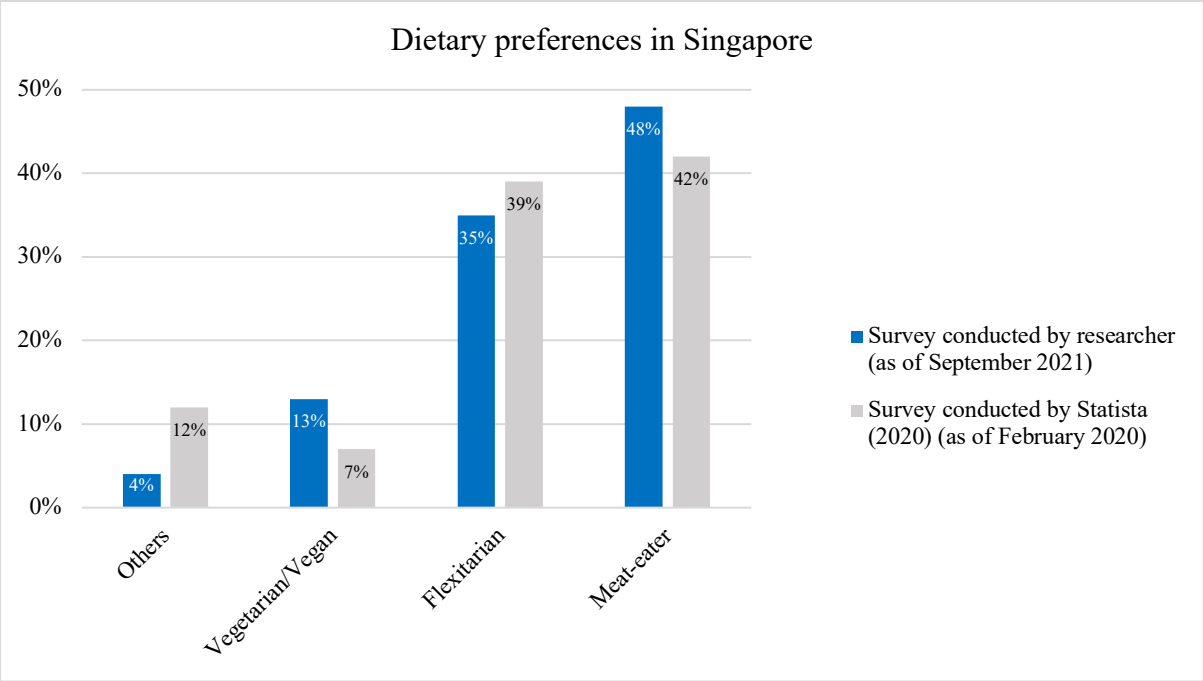


Figure 5: Survey conducted by researcher and by Statista (2020) on dietary preferences in Singapore

Hence, there is a well-represented group of survey participants whose diets belong to "meat-eater" or "flexitarian". This is the group where the switch from conventional to alternative proteins is the most vital, and it is thus essential to analyse their perceptions and practices regarding alternative proteins. Further information on the demographics of survey respondents can be found in Appendix 3.

A combination of both interviews and surveys to reach different actor groups throughout the value chain helped to deepen the understanding of the developments and innovation dynamics in the alternative protein food system and to discuss emerging insights from the event analysis. Desk research was also used to triangulate the collected data throughout the research phases.

3.3 Data collection limitation

The data collection occurred from July to September 2021, when the COVID-19 pandemic was still ongoing in Singapore. Hence, several factors affected the quantity and quality of data collected:

- The inability to conduct ethnographic research on consumers as the researcher could not be located in Singapore due to the pandemic. Ethnographic research helps to triangulate the survey results. The risk of mismatch between survey responses and actual behaviours may limit the accuracy of the survey findings;
- The reluctance of key actors to share essential details about future development plans or strategies to protect their competitive advantages;
- The possibility of deliberate skewing of responses to cast the research in a direction that best suits the participants. Nonetheless, the breadth of questions asked and of the participants interviewed serve to reduce the skewness of the responses;
- The inability to collect some primary and secondary data for the initial range of indicators proposed. As a result, the breadth and range of indicators were curtailed down to essential indicators critical to analysing the transition. This allowed the researcher to focus on the depth, rather than breadth, of the analysis; and
- The inability to seek interviews with incumbent companies (both meat manufacturers and food processing companies), as all interview requests sought from these companies were not responded to. Responses from these actor groups were thus sought from interviews with other stakeholders and desk research.

3.4 Scope of research

While alternative proteins also include alternative dairy that is progressively on the rise, the transition process for alternative dairy may look quite different from alternative meat. Due to the limited research timeframe and the intention to focus on the depth of the transition process, alternative dairy is not included within the scope of this paper. Hence, the focus of this thesis is on alternative meat products in Singapore. The taxonomy is shown in Table 3.

In addition, plant-based diets have been part of Singapore's cuisines, owing to and often exclusive to religious groups. Correspondingly, there are some established niche companies providing alternative protein products to these demographics, but their innovation and uptake have stayed relatively silent. These niches stayed as niches without influencing the regime structures and rules until niche entrepreneurs started entering the scene in the 2010s and until political actors bestowed legitimation to the niches. Therefore, this research focused on the niche entrepreneurs whose visions and innovations exhibit larger potential for mass adoption.

Lastly, this research seeks to analyse the current transition process. While expectations and beliefs relating to the next ten years were sought in this research, many other factors will affect the transition in the future in a complex manner. Hence, predictions of future transition were not scoped in this research.

3.5 Data analysis methodology

Through the interviews, surveys and desk research, the development of the alternative protein food system was explored from different perspectives. Using Atlas-ti, all interviews and surveys were transcribed and coded. The codes were grouped further and analysed to grasp deeper insights into the relationships and patterns of influence in the transition. New indicators surfaced during the process of coding, for which they were either grouped under the relevant variable or given a new variable on its own. After coding, a co-occurrences table was created within Atlas-ti to illustrate the intersecting quotes between the variables and indicators, thus highlighting the interactions between the variables. From the findings in phases one to four, the key drivers and barriers were identified in the fifth phase. Lastly, the influence of these key drivers and barriers on the pathway of the transition was scrutinised in phase six.

3.6 Validity and reliability

The reliability of research comprises the accuracy and consistency in measuring the variables, whereas validity encompasses internal and external validity (van Thiel, 2014). The former describes the cogency of the research itself and the latter refers to the extent that the research findings can be generalised (van Thiel, 2014). Following van Thiel (2014), the small number of units of study (a single case study in this case) can endanger its reliability and validity.

To overcome the potentially low reliability, all steps taken and data sources used were documented in this chapter so that the entire research process can be reviewed and easily replicated thereafter. A case study protocol was also utilised as standardising case studies facilitates replication (van Thiel, 2014). In addition, semi-structured interviews and structured surveys were conducted where the questions were clearly and closely related to the conceptual framework. The use of an interview manual ensured that the interview followed a set pattern. This enhances operationalisation and replicability, and thus reliability.

As the case study is context-specific to Singapore, findings from this research are hardly generalisable, thus limiting the external validity of the case study. The case study is also exposed to the risk of being interpretation-based and there may be other variables not covered within the case study that explain the phenomena. A solution to overcome the low validity is triangulation, where desk research was used to supplement the case study. At the end of the research, the results were shared with key experts in the alternative protein sector in Singapore to enhance its internal validity before publishing the findings.

3.7 Operationalisation

This subchapter introduces a qualitative mix of subjective and objective indicators to provide information on the perceptions and strategies of the relevant actors in response to the developments in the alternative protein food system in Singapore. These variables were obtained directly from theory and their assessment is therefore vital in testing the theory's applicability. Some variables already have indicators developed in literature, whereas some were developed specifically for this research. Table 5 details the indicators for the independent variables, whereas Table 6 details the indicators for the dependent variable. Both tables include the values, type and source of data for each indicator.

Table 5: Indicator table for the independent variables (Second to fourth phases)

Variables (Codes)	Sub-variable	Indicators	Values	Type of Data	Source of data	Literature
Landscape factors (L)	Exogenous factors that potentially drive or hinder the transition	L1: Influence of exogenous factors that impact the transition (e.g. supply chain shocks, health trends, shocks relating to meat consumption due to zoonotic diseases)	- Open-ended - The extent of influence: 5-point Likert scale (with five being the most favourable for the transition)	Objective	Desk research	MLP (Geels, 2002)
Regime (Political actors) (P)	Reactions to the landscape factors	P1: Amount and adequacy of government funding	- 5-point Likert scale (with five being the most favourable for the transition)	Objective and subjective (for the assessment of the adequacy of funding)	Desk research and in-depth interviews	- Typology of Transition Pathways (Geels & Schot, 2007) - MLP (Geels, 2002) - Linking mechanisms (Elzen et al., 2012)
		P2: Extent of network anchoring	- 5-point Likert scale (with five being the most favourable for the transition)	Objective		
		P3: Extent of regulatory pressure on the alternative protein sector	- 5-point Likert scale (with five being the most favourable for the transition)	Objective		
Regime (Incumbent meat companies, food processing companies and retailers) (A)	Reactions to landscape, political, entrepreneurial and consumer factors	A1: Extent of lobbying against alternative protein sector	- 5-point Likert scale (with five being the most favourable for the transition)	Objective	Desk research and in-depth interviews	- Typology of Transition Pathways (Geels & Schot, 2007) - MLP (Geels, 2002)
		A2: Types of responses	- The favourability of response: 5-point Likert scale (with five being the most favourable for the transition)			

Niche entrepreneurs (TIS) (start-ups, innovation clusters) (N)	Entrepreneurial activities	N1: Number of new entrants	- 5-point Likert scale (with five being the most favourable for the transition)	Objective	Desk research and in-depth interviews	TIS (Bergek et al., 2008)
		N2: Breadth of products	- 5-point Likert scale (with five being the most favourable for the transition)			
		N3: Breadth of technologies	- 5-point Likert scale (with five being the most favourable for the transition)			
	Resource mobilisation	N4: Availability of monetary capital	- 5-point Likert scale (with five being the most favourable for the transition)	Objective		
		N5: Availability of human capital	- 5-point Likert scale (with five being the most favourable for the transition)			
	Knowledge development and diffusion	N6: Amount of knowledge developed	- 5-point Likert scale (with five being the most favourable for the transition)	Objective		
		N7: Bibliometrics *(e.g. number of citations, volume of publications, orientation/direction of publications)*	- 5-point Likert scale (with five being the most favourable for the transition)	Objective		
		N8: Extent of horizontal diffusion of knowledge	- 5-point Likert scale (with five being the most favourable for the transition)	Objective		
		N9: Extent of vertical diffusion of knowledge	- 5-point Likert scale (with five being the most favourable for the transition)	Objective		
Consumers (C)	"Images", "Skills" and "Materials" relating to alternative proteins (vis-à-vis conventional proteins)	C1: Images: a. Perceived nutritional superiority b. Perceived price c. Perceived environmental impacts d. Perceived taste e. Perceived accessibility	- 5-point Likert scale (with five being the most favourable for the transition)	Subjective	Desk research and surveys	Social Practice Theory (SPT) (Shove & Pantzar, 2005)
		C2: Skills: Familiarity with obtaining access to alternative proteins and using alternative proteins in cooking				
		C3: Materials: Availability of alternative proteins in supermarkets and F&B outlets				

Table 6: Indicator table for the dependent variable (Sixth phase)

Variables	Sub-variable	Indicators	Results	Types of data	Source of data	Literature
Pathway of transition (DV)	0. Reproduction process	- Landscape pressure almost non-existent	- Regime remains stable	Objective	Synthesis of information from phases 2-4	Typology of transition pathway (Geels & Schot, 2007)
	1. Transformation path	- Timing of interactions: Moderate landscape pressure occurring when niches are underdeveloped - Nature of interactions between the regime and niches: Symbiotic (Added into the regime to solve problems, rather than replacing it)	- Regime remains somewhat stable but symbiotic niche innovations are adopted into the regime			
	2. De-alignment and re-alignment path	- Timing of interactions: "Divergent, large and sudden" landscape pressure occurring when niches are underdeveloped - Nature of interactions between the regime and niches: Competitive	- Loss of faith by incumbent actors (e.g. declining research and development (R&D) investments in the meat sector) - Several niches come into being and compete for space, but eventually, one niche dominates and establish the foundation of a new regime			
	3. Technological substitution	- Timing of interactions: "Divergent, large and sudden" landscape pressure occurring when niches have sufficiently developed - Nature of interactions between the regime and niches: Competitive	- Intense landscape pressure coinciding with the strongly developed TIS, causing the downfall of incumbent meat companies (e.g. reduction in market share, revenue) - The strongly developed TIS takes over the regime			
	4. Reconfiguration pathway	- Timing of interactions: Moderate landscape pressure occurring when niches are underdeveloped - Nature of interactions between the regime and niches: Symbiotic - More adjustments in the regime compared to DV1	- Adoption of symbiotic niche innovation into the regime - Adjustments in regime include changes in technology, user perceptions and practices			

Chapter 4: Research findings

In this chapter, the developments in the alternative protein system are detailed, followed by an analysis of the data collected according to the variables presented in the conceptual framework. Citations from the interviewees are also included in the data analysis, where the reference to the interviewees follows the nomenclature in Chapter 3.2.

4.1 Background, timeline and map of actors

Before 2017

In Singapore's early years of development, agriculture was a critical livelihood and food source to the residents (Centre for Liveable Cities [CLC], 2018). 9% of Singapore's population depended, directly or indirectly, on farming and fishing for a living in 1970 (CLC, 2018). Subsequently, along with population growth and urban development, farmlands gave way to other sectors such as housing (CLC, 2018). As local food production declined, Singapore became more reliant on imports by the 1980s (CLC, 2018). By the mid-2000s, Singapore imported 90% of its food (CLC, 2018). Singapore's vulnerable position as an import-dependent country was made apparent by the global food crisis in 2008, which urged the development of the Food Security Roadmap in 2013 (Agri-Food and Veterinary Authority of Singapore [AVA], 2013; CLC, 2018). The Food Security Roadmap comprises "core", "supporting", and "enabling" strategies (AVA, 2013). Until recently, alternative proteins had not been recognised as an essential pillar for Singapore's food security. Local production, diversification of import sources and stockpiling were the "core" strategies, but it primarily focused on urban farming and aquaculture (CLC, 2018). Table 7 shows Singapore's Food Security Roadmap, including its "core", "supporting" and "enabling" strategies:

Table 7: Food Security Roadmap

Food Security Roadmap for Singapore (Adapted from AVA, 2013)		
Core strategies:	**Supporting strategies:**	**Enabling strategies:**
- Diversification of import sources (invest abroad, industry development) - Offsetting of limitations in diversification (local production, stockpiling)	- Research and development (R&D) - Food wastage reduction - Strengthening of infrastructure - Financial instruments - Welfare/ affordability	- Cross-government coordination - Emergency planning - Communication - Market monitoring - Fiscal, legal and regulatory framework

After 2017

The recognition of alternative proteins as an essential pillar, and the corresponding state investments, occurred more recently in the last five years, particularly in 2019/2020 with the establishment of the "30 by 30" goal and with the onset of the COVID-19 pandemic. The "30 by 30" goal reflects Singapore's ambition to locally produce 30% of its food consumption needs by 2030, up from less than 10% currently (Lim, 2021). The "30x30 Express Grant" call

was later launched in April 2020 to speed up the progress towards achieving the "30 by 30" goal in response to the COVID-19 disruptions to food security (SFA, 2020a).

The 2020 Singapore Food Story campaign was officially launched by the Ministry of Sustainability and Environment (MSE) amidst concerns about COVID-19 related supply chain disruptions and climate change effects on food supply (MSE, 2020). To accelerate the research and development of the Singapore Food Story, the Singapore Food Story R&D programme led by Agency for Science, Technology and Research (A*STAR) and Singapore Food Agency (SFA) was launched in end-2019 (SFA, n.d.-d). As part of this programme, S$144 million has been set aside to support (i) sustainable urban food production, (ii) the development of future foods: biotech-based protein production and (iii) food safety science and innovation (SFA, n.d.-d), as illustrated in Table 8.

Table 8: Target focus areas for the themes under the Singapore Food Story R&D programme

Target focus areas for the themes under Singapore the Food Story R&D programme (Adapted from SFA, n.d.-d)		
Sustainable Urban Food Production	**Future Foods: Advanced Biotech-based Protein Production**	**Food Safety Science & Innovation:**
- Genetics - Nutrition - Disease & Health Management - With elements of smart sensors for urban production systems - Nutrient & quality preservation for farm produce	- Discovery: Computational Biology, Cultivated protein - Translational: Microbial Protein, Plant Protein, Scale-Up	- Food Safety Science for Emerging Risks - Intelligent Supply Chain - Understanding Consumer Behaviour towards Food

More than half of the S$144 million has been set aside specifically for the novel protein pillar (Interviewee R12), highlighting the recognition of its significance in contributing to Singapore's food security as its production requires significantly less land. Besides, producing proteins is also aligned with Singapore's nutrition guidelines which encourage a quarter of a meal intake to be filled with proteins (Ministry of Health [MOH], n.d.). However, unlike its western counterparts (e.g. European Commission's Farm to Fork Strategy, which aims to reduce environmental impacts associated with meat production through a protein transition (EC, 2020)), Singapore's push for alternative proteins is motivated by its drive for enhanced food security, and less so by environmental reasons. This difference in motivation has an impact on the transition, which is analysed in the latter part of this chapter.

Apart from the Singapore Food Agency (SFA), other key stakeholders and initiatives increasingly enter the picture, as seen in the timeline in Table 9.

Table 9: Instrumental events contributing to the growth of the alternative protein sector in Singapore[1]

Year	Description	Source
2017	Innovate 360, the first incubator in Singapore with manufacturing facilities for food tech start-ups, was established. It was spun out from Cheng Yew Heng - Singapore's oldest sugar manufacturer and is supported by Enterprise Singapore (ESG).	Startup SG (n.d.-a)

[1] The table does not illustrate all but only key, relevant events.

2018	FoodInnovate, a multi-agency collaboration to nurture the food manufacturing industry in the innovation aspect in Singapore, was established. Agencies include ESG, A*STAR, Economic Development Board (EDB), IPI (Innovation Partner for Impact) Singapore, JTC Corporation and SFA.	ESG (n.d.)
	ESG partnered with one local life sciences accelerator and five global agri-food tech accelerators under the Start-up SG Accelerator programme to guide agri-food tech start-ups in raising funds and developing, commercialising and internationalising products.	ESG (2020b)
2019	Temasek, ESG and Tyson Foods committed to contributing about 40% of Big Idea Ventures (BIV)'s New Protein Fund.	ESG (2020a)
	In January 2019, the investment arm of ESG, SEEDS Capital, engaged seven co-investment partners to invest more than S$90 million into start-ups in the early-stage, agri-food tech space.	ESG (2020b)
	Singapore pledged funding of S$80 million into cell manufacturing - crucial to cultivated protein.	Teh (2019)
	Ministry of Trade and Industry (MTI) established Agri-Food Innovation Park (AFIP) to fuel innovation in the agri-tech ecosystem, including alternative proteins.	MTI (2019)
	In September 2019, A*STAR inked a Memorandum of Understanding with Wageningen University and Research (WUR) to seek research collaboration opportunities in Food Science and Processing. WUR is also considering establishing a joint lab housed in the Singapore Institute of Food and Biotechnology Innovation (SIFBI). This partnership will facilitate knowledge exchange around alternative proteins.	A*STAR (n.d.-a)
	In December 2019, grant calls for R&D in sustainable urban food production and future foods were put in motion. The thematic areas under the grant call for R&D in future foods cover microbial, plant-based and cultivated proteins, with grants of up to S$15 million per programme/proposal.	A*STAR (n.d.-b)
2020	Singapore Institute of Food and Biotechnology Innovation (SIFBI) launched in April 2020 to synthesise the capabilities of several national research institutes and facilitate joint research and development (R&D) for developing novel foods. SIFBI will amalgamate A*STAR's current capabilities, leverage existing collaborations and improve economic value capture for the food ecosystem in Singapore.	A*STAR (n.d.-c)
	Singapore Food Bowl programme launched in May 2020 to assist agri-food tech start-ups in commercialising novel technologies that are key to Singapore's food security requirements, with help from ESG and Dole Packaged Foods.	ESG (2020a)
	A*STAR and Ministry of Business, Innovation and Employment (MBIE) in New Zealand jointly launched a 3-year bilateral grant call on Futures Foods, with plant-based alternative proteins (priority on algae and microbial proteins) at its core.	A*STAR (n.d.-a)
	In Nov 2020, Temasek signed an agreement with the Agency for Science, Technology and Research (A*STAR) to set up the Food Tech Innovation Centre to speed up the commercialisation of food technologies.	MTI (2021)
	The world's first regulatory approval was granted to cultivated chicken from Eat Just in Dec 2020, later launched for sales in April 2021.	SFA (n.d.-d)
	SingCell, a stem cells contract development and manufacturing organisation (CDMO) established in Singapore. It offers clean meat companies process development and contract manufacturing services.	Startup SG (n.d.-b)
2021	Bühler and Givaudan launched a joint protein innovation centre in April 2021.	MTI (2021)
	Archer Daniel Midlands (ADM) launched a plant-based innovation lab in April 2021.	ADM (2021)
	Avant Meats announced in April 2021 that it is establishing new R&D and pilot production facilities in Singapore, created with the support of EDB.	EDB (2021)
	Firmenich announced in May 2021 that it is establishing a Culinary & SmartProteins Innovation Hub in Singapore, with EDB as a partner in this investment.	Firmenich (2021)
	Nanyang Technological University (NTU), SFA and A*STAR launched Future Ready Food Safety Hub (FRESH) in April 2021, which will boost food safety-related R&D capabilities, develop talent and enhance food safety risk communications.	MSE (2021)
	In 2021, the Singapore Institute of Technology (SIT), in partnership with ESG and JTC, will operate FoodPlant, a food processing facility that seeks to offer companies with skills, knowledge and equipment to quicken the development of meat substitutes.	SIT (2021)
	SGProtein, a Singapore-based contract manufacturing platform for meat analogues established.	SGProtein (2021)
	In July 2021, Esco Aster, a contract development and manufacturing organisation based in Singapore, was awarded the world's first approval and correspondingly began producing cultivated chicken.	Tan (2021)

By 2021, the alternative protein sector in Singapore flourished into a multi-stakeholder ecosystem with various actors across the globe and value chain, thus positioning Singapore as a notable alternative protein hub. Appendix 5 illustrates a snapshot of the current ecosystem in Singapore.

4.2 Data analysis of independent variables

This subchapter presents the data acquired from interviews, surveys and desk research according to the variables captured in the conceptual framework, as illustrated in Figure 4. Concurrently, the data analysis responds to each sub-question, which builds up to the main research question outlined in Chapter 2. A direct response to the main research question is detailed in Chapter 5.

4.2.1 Landscape factors

Indicators: Extent of influence of exogenous factors on the transition

Landscape factors are exogenous elements that impact the transition to sustainable agri-food systems (El Bilali, 2019b). Beyond the control of the regime and niche actors, these factors have two main functions in the transition process – pressurising the regime and creating opportunities for niches (El Bilali, 2019b).

Undeniably, COVID-19 has emphasised the need to strengthen global food security as it disrupted food supply chains and caused prices to fluctuate. This exerts pressure on the regime to diversify its food sources to buffer against unexpected disruptions whilst creating opportunities for alternative proteins, as interest in developing novel foods to boost food security is piqued in various countries. The pandemic has incentivised Singapore further to accelerate local food production. For example, in September 2020, SFA bestowed S$39.4 million to nine companies under the "30 by 30 Express Grant" to promptly boost local food production over the next 6 to 24 months, including alternative proteins (MSE, 2020).

COVID-19 media reports have also shone the light on meat production practices, as concerns are raised around the spread of infectious disease and excessive use of antibiotics in intensive animal husbandry (Attwood & Hajat, 2020). COVID-19 rallies consumers to demand greater transparency in meat production whilst motivating individuals to choose cleaner proteins (Attwood & Hajat, 2020). During the COVID-19 pandemic in the United States, the sales of plant-based alternative protein more than doubled in April 2020 compared to the previous year (Terazono & Meyer, 2020). Increased priority on health, coupled with growing environmental and ethical concerns, also contribute to the swell in demand (Bashi et al., 2019). The opaqueness and unsustainability inherent to the current regime are thus increasingly pressurised, generating opportunities for more sustainable niches to leverage.

Although these landscape factors can potentially trigger transformations within the agri-food sector, Lamine (2011) warns that transitions are constrained by various aspects, specifically

the lock-in consequences of routines and rules embedded in the incumbent agri-food industry. These inhibitions and lock-ins are examined in the later subchapters.

Overall, the Likert scale relating to the influence of exogenous factors is assessed to be 4, with reasons provided in Table 10.

Table 10: Likert scale of landscape factors

Indicators	Likert scale[2]	Reasons
Influence of exogenous factors	4	There is a strong influence of exogenous factors, particularly due to Singapore's land constraints. However, the influence of these factors is constrained by lock-ins and path dependencies.

4.2.2 Regime responses

As mentioned in Chapter 2, socio-technical regimes refer to the formations of incumbent actors and technologies and their accompanying rules (Geels & Schot, 2007). In this research, the incumbent food system, typically heavy in conventional proteins (i.e. meat and seafood produced from conventional agricultural practices), is conceptualised as the socio-technical regime. Järnberg et al. (2018) and Bui et al. (2016) emphasise the crucial role of authorities in the transition, which is particularly relevant to Singapore given its hegemonic regime (Ng, 2018). Hence, in this subchapter, responses by regime actors, including governmental actors, incumbent meat producers and food processing companies, are analysed, as well as their interactions with the niches. Critical attention is also paid to the regime rules and lock-ins, as they highlight the capacity for niches to break through the regime.

4.2.2.1 Governmental actors' responses

Indicators: Amount of governmental funding, the extent of regulatory pressure and network anchoring

With the recognition of alternative proteins as an essential contributor to Singapore's food security, the government has established many linking mechanisms to nurture and legitimise the niches. The extent of governmental support and network anchoring in Singapore is recognised by 12 out of 16 interviewees (Interviewees R1, R2, R3, R5, R6, R7, R8, R9, R10, R14, R15, R16), as they collectively described the government to be proactive and one of the most involved governments globally in driving the alternative protein ecosystem.

"So, what the Singapore government does is (to develop) a hub. They believe in the economics of agglomeration of cluster effects, so they are trying to bring different actors together - the investors, innovators, scientists, universities, early-stage grant funding and the promise of a friendly regulatory system to catalyse the sector." (Niche entrepreneur – R10).

Network anchoring is a key governmental strategy used in fostering the alternative protein ecosystem in Singapore. Several alternative protein entrepreneurs and key stakeholders across the value chain have been anchored in Singapore by governmental agencies. A*STAR and the Economic Development Board (EDB) collaborate to identify high-potential growth

[2] Scale from 1-5, with 5 being the most favourable for the transition.

entrepreneurs abroad and attract them into Singapore through various means, such as Temasek's investments in them (R4, R12, R13). Innovation centres, incubators, co-manufacturing plants and shared facilities have been established by the governmental agencies and by the key stakeholders anchored by the governmental agencies. This network anchoring further fosters the ecosystem. Examples of network anchoring mechanisms are detailed in Table 11.

Table 11: Network anchoring and expansion of the alternative protein sector[3]

Year founded	Title	Supported/ established by	Objective	Source
2017	Innovate 360	Supported by ESG	Incubate and provide food tech start-ups with some resources, including its manufacturing facilities	Startup SG (n.d.-a)
2018	Agri-Food Innovation Park (AFIP)	Established by MTI	Fuel innovation in the agri-tech sector, including alternative proteins	MTI (2019)
2020	Singapore Institute of Food and Biotechnology Innovation (SIFBI)	Established by A*STAR	Amalgamate A*STAR's current capabilities, leverage existing collaborations and improve economic value capture for the food sector in Singapore	A*STAR (n.d.-c)
2020	Singapore Food Bowl Programme	Supported by ESG and EDB	Accelerate start-ups focused on technologies that can substantially enhance productivity in aspects aligned with Singapore's "30 by 30" food pillars, including alternative proteins	ESG (2020a)
2020	Food Tech Innovation Centre	Established by A*STAR and Temasek	Speed up the commercialisation of food technologies	MTI (2021)
2021	Bühler and Givaudan Joint Protein Innovation Centre	Supported by EDB	Co-create plant-based food experiences with food processing companies, start-ups and university researchers in the Asia Pacific by amalgamating Bühler's extrusion and processing technology with Givaudan's expertise in flavour, taste, and product development	MTI (2021)
2021	ADM Plant-based Innovation Lab	Supported by EDB	Efficiently and effectively customise products for the Asian consumer palate by leveraging its panel of experts in proteins, texturing ingredients and flavours	ADM (2021)
2021	NTU Future Ready Food Safety Hub (FRESH)	Established by Nanyang Technological University (NTU), SFA and A*STAR	Work towards boosting food safety-related R&D capabilities, developing talent and enhancing food safety risk communications	MSE (2021)
2021	SIT FoodPlant	Established by the Singapore Institute of Technology (SIT), ESG and JTC	Offer companies with skills, knowledge and equipment to quicken the development of meat substitutes	SIT (2021)
2021	SGProtein	Supported by ESG	Offer contract manufacturing services for meat analogues	SGProtein (2021)
2021	SingCell	Supported by ESG	Offer clean meat companies process development and contract manufacturing services	Startup SG (n.d.-b)
2021	Esco Aster	Supported by ESG	Offer clean meat companies process development and contract manufacturing services; recently approved to produce cultivated chicken in Singapore	Tan (2021)

[3] The table does not illustrate all but only key, relevant actors.

Announced in 2021; launch date uncertain	Avant Meats R&D and pilot production facilities	Supported by EDB	Provide manufacturing services for cultivated meat and fish in Singapore	EDB (2021)
Announced in 2021; launch date uncertain	Firmenich Culinary & SmartProteins Innovation Hub	Supported by EDB	Develop solutions in Meat Proteins and Plant-based alternatives by consolidating and leveraging technical expertise in aroma, flavour, taste, umami and texture solutions from Campus and Firmenich	Firmenich (2021)

This aggressive expansion of the network and the amplification of contacts amongst these actors enable knowledge exchange and mutual learning (Ingram, 2015), facilitating shared visions. Shared visions include a view on how the transition should look like and a consensus of what is currently lacking to drive the transition further (R2, R14, R15, R16). For example, through knowledge exchange and mutual learning, five interviewees expressed that the research and production facilities are falling short (R2, R5, R6, R10, R11). Hence, actor organisations like Innovate 360, SGProtein, SingCell and Esco Aster are increasingly coming into the scene to bolster production facilities, enabling niche entrepreneurs to focus on their innovation without worrying about building their production facilities or applying for approvals for production (R15, R16; Tan, 2021). Nonetheless, the sector is incredibly nascent at this point and such facilities are only starting to grow in size. As such, the current cost per production unit is relatively high (R2, R3, R5, R9, R10, R11). This has repercussions on the consumer uptake of alternative proteins, as price is a paramount consideration in one's protein choice – evident in the survey results.

As the first country globally to approve the sales of cultivated meat in December 2020 (SFA, n.d.-b), the regulatory system led by the Singapore Food Authority (SFA) has been described as a "great blend of caution and progressiveness" (R8). There is a consensus on this perspective amongst the other interviewees (R1, R2, R3, R5, R6, R7, R10, R11, R12, R13, R14, R15, R16). SFA collaborates with other governmental agencies, particularly A*STAR, to better understand the science and process behind developing novel proteins (R12, R13). SFA also works closely with other key stakeholders, including accelerators, non-profit organisations and alternative protein entrepreneurs, to develop a cautious yet progressive regulatory system (R4). This is an example of institutional anchoring introduced in the MLP concept, as institutional rules built inside the niches are translated into the regime. One example is the development of novel protein frameworks which consider the niche entrepreneurs' voices. Interactions between the political actors and niche actors thus gradually initiate changes in public policies, as in other empirical case studies analysed by many sustainability transition scholars (e.g. Bui et al., 2016). As Bui et al. (2016) expound, this influence in local policies indicates some impact in the regime by the niches.

However, the extent of regulatory progressiveness differs amongst the protein types (R12). Acknowledging fermentation-based and cultivated protein as the key pillars contributing to Singapore's food security and recognising that other countries have yet to take bolder steps in regulating these novel proteins, Singapore strives to take leadership in the regulatory system for these proteins (R12). In comparison, plant-based and insect proteins are perceived as less significant in contributing to Singapore's food security. With other nations already taking steps

to regulate and approve plant-based and insect proteins, Singapore realises that it can "just take reference and not take leadership" (R12). As a result, although insect protein has been consumed for centuries in Asia, it has yet to be approved for commercialisation in Singapore (R7), despite the regulatory approval of a highly novel protein type – cultivated protein.

"The main drivers (of Singapore's food security) will be cultivated and microbial proteins due to the land space required and the talents we can leverage from the biotech sectors. Thus, we actively take leadership in the regulations for these proteins. The others (plant-based and insect proteins) are more challenging because of Singapore's lack of land and talent. Therefore, we prefer to take reference from other countries and not take leadership for those proteins."(Public sector research institute - R12).

Further, El Bilali (2019b) suggests that government funding is also a linking mechanism. Since establishing the "30 by 30" goal and the onset of the COVID-19 pandemic, a series of state funding has been launched, as detailed in Table 12.

Table 12: List of governmental funding specific to alternative proteins[4]

Title	Description	Source
"30x30 Express" grant call	Close to S$40 million grant launched in April 2020 to grow local agri-food enterprises and accelerate local food production in response to the COVID-19 disruptions to food security.	SFA (2020)
Singapore Food Story R&D Programme	Launched in end-2019, S$144 million is set aside to support sustainable urban food production, developing novel protein production, promoting food safety science and innovation and consumer science and risk communication.	A*STAR (n.d.-d)
Singapore-New Zealand Bilateral Research Programme on Future Foods	Launched in 2020, A*STAR and Ministry of Business, Innovation and Employment (MBIE) called for proposals under the Singapore-New Zealand Bilateral Research Programme on Future Foods. The objective is to synthesise key research organisations in both countries to facilitate scientific knowledge exchange around Future Foods. Each proposal must focus on a fundamental technical challenge and possess a new technical application in Future Foods. Scientific research into plant-, microbes- or fungi-based protein must also be at its core.	A*STAR (n.d.-a)

While desk research has revealed a series of grants, as seen in Table 12, it is not easy to assess its adequacy from a researcher's point of view. Therefore, the question of its adequacy has been posted to many interviewees, to which different responses have been garnered. Interviewees from the governmental sector (R4, R12, R13) have generally maintained that state funding is adequate. In contrast, many interviewees, including the accelerators, entrepreneurs and non-profit organisation (R5, R6, R8, R9, R10, R11, R14, R15, R16), expressed that it is often inadequate and restrictive. This illustrates a distinction in the perspective of the funding between the organisers and intended recipients. A deeper probe into the distinction in perspectives in Appendix 6 can guide policymakers in improving the structures and quantities of state funds to nurture the transition further.

[4] The table does not illustrate all but only key, relevant governmental grants.

4.2.2.2 Incumbent actors' responses

Indicators: Extent of lobbying, type of responses

Responses from interviewees from incumbent companies in Singapore indicate a consensus regarding the extent of lobbying and type of responses (R4, R6, R8, R10, R13). Singapore is considered "agricultural neutral" (R4) due to the minimal local food and meat production. Hence, "there is no resistance and (the political actors) can get away with as much approach as they want with the protein sector. There are only eight farms, so Singapore can take a firm stance, with the full confidence that no one is losing jobs." (R10). This makes it easier for the Singapore government to extend stronger support to the alternative protein sector, unlike other countries where the animal agriculture industry plays a significant economic and consequently, political role (R13). In this unique context, the discussion of incumbent actors thus includes food processing companies noteworthy in Singapore's food supply chain.

The use of alternative proteins can be advantageous to food processing companies, particularly as the prices of conventional proteins increase. Many of these companies produce "food composites" such as fish- or meatballs, a mashed-up combination of seafood or meat and flour. As the meat and seafood prices increase, incumbent food processing companies can substitute conventional with alternative proteins to maintain the price levels, of which the familiar taste would be a trigger for adoption amongst consumers. Besides, creating alternative protein-based composites are potential "additional revenue streams" (R8; R6 spoke along the same lines) for these companies while buffering against disruptions in price or supply of the conventional proteins and still leveraging their current food processing techniques and distribution channels without much disturbances. However, despite this opportunity, many interviewees contended that the local food processing companies tend to adopt a hesitant "wait-and-see" approach and are not keen on moving first (R6, R9). This "wait-and-see" approach arises likely because the regime rules remain largely intact, particularly when normative rules reinforce consuming conventional proteins, which reduces the legitimacy of alternative proteins. Therefore, this makes them more cautious about being too active in pursuing alternative proteins, despite being a potential revenue stream. Local food processing companies like Tee Yih Jia only arrived at their decision on their plant-based line after years of discussion and contemplation (R6). However, desk research has not confirmed this information, suggesting that such aspects of decision-making may have been under-emphasised in public reports.

4.2.2.3 Overall analysis of regime responses

Overall, the Likert scale relating to the regime responses are assessed in Table 13:

Table 13: Likert scale of regime responses

Indicators	Likert scale[5]	Reasons
P1: Amount and adequacy of governmental funding	2	There is a recent increase in funding, but it is still perceived to be inadequate and restrictive.

[5] Scale from 1-5, with 5 being the most favourable for the transition

P2: Extent of network anchoring	3	Network anchoring is a key governmental strategy used in fostering the ecosystem and strengthening the infrastructure through facilities built by stakeholders founded in or brought into Singapore. However, the infrastructure is still falling short in scale.
P3: Extent of regulatory pressure	4	Regulatory system is perceived to be strict yet progressive, but it is only limited to specific alternative protein streams.
A1: Extent of lobbying	5	There is little/no known lobbying due to the insignificant presence of meat manufacturers in Singapore and their limited collective ability to resist the alternative protein sector.
A2: Type of response (from incumbent companies)	2	Food processing companies are generally receptive but slow to get on board.

4.2.3 Strength of niches

Whether or not niches can scale up and out and eventually break through the regime depends on their robustness and maturity (El Bilali, 2019b), amongst other factors. This subchapter takes guidance from Bergek et al. (2008) to assess the strength of the alternative protein sector in Singapore, with respect to 3 broad factors: entrepreneurial activities, knowledge development and diffusion and resource mobilisation.

4.2.3.1 Entrepreneurial activities

Indicators: Number of new entrants, breadth of products and technologies

Plant-based diets have been part of Singapore's cuisines even before its independence, owing to and often limited to religious groups that advocate for compassion towards all living beings. Nonetheless, innovation in this space has remained relatively silent, with plant-based mock meats typically made from soy and wheat being the key alternative proteins. The outreach, visions and values of these plant-based diets are also often exclusive to religious groups. These niches stayed as niches without influencing the regime structures and rules until niche entrepreneurs started entering the scene in the 2010s. The key turning point for the nurturing and legitimation of the niches is the "30 by 30" goal established to augment food security amidst landscape factors like climate change and the onset of the COVID-19 pandemic. This is an example of how landscape factors pressurise the regime, which then motivates the regime actors (i.e. the local authorities) to recognise the importance of alternative proteins in contributing to Singapore's food security as introduced in the concept of MLP.

As mentioned under Chapter 4.2.2.1, network anchoring mechanisms developed by the regime significantly expand the network and attract entrants into Singapore's alternative protein landscape since the "30 by 30" goal. Stakeholders throughout the alternative protein value chain have been invited into or attracted to Singapore, as seen in Table 11, thus positioning Singapore as a global alternative protein hub. Being the first country globally to approve cultivated meat for commercialisation has a significant role in attracting cultivated protein start-ups and corresponding investors into Singapore (R10, R11, R13), a well-intended effect of the progressive regulatory system.

Regarding the breadth of technological development, the technologies deployed and researched in biomedical science and biotechnology are transferable to alternative proteins, particularly for cellular agriculture (R3, R8, R12). This is further supported by Specht et al. (2018). Hence, Singapore's expertise in biomedical science and biotechnology (Yeoh, 2008) presents valuable opportunities to expand the verticals in alternative protein – an example being fermentation-based cellular agriculture, which is different from tissue engineering-based systems in that no tissue from a living animal is used (Stephens et al., 2018). Instead, organic molecules are produced by fermentation using yeast, algae or bacteria and recombinant DNA (Stephens et al., 2018). These molecules can be utilised to bio-fabricate animal products (Stephens et al., 2018). With technology advancing rapidly, the interviewees (R1, R2, R6) contended that there are endless possibilities in the breadth of alternative protein technologies, from cultivated protein to fermentation. However, a gap still exists between the current stage and the potential of this industry, as the sector is relatively nascent (R3) and not much deep technology has been developed (R6).

Public sector research institute - R12 commented, "The pros of cultivated and microbial protein arose from the established processes in Singapore. We have a lot of pharmaceutical, biopharmaceutical companies producing this similar technology. So, we do have the talent and they know how to do this kind of stuff, so knowledge will not be a barrier for these two particular pillars."

The breadth of alternative protein products is also expanding (Ignaszewski, 2021), from meat patties to those more commonly found Asian cuisines such as dumplings and luncheon meat, as entrepreneurs understand the key to success is the localisation of flavours and textures. Six interviewees (R1, R2, R5, R6, R7, R15) asserted this. Interviewee R6 also noted that "the sector is not just limited to plant-based meat - as people are demanding more protein, alternative proteins can be used in many applications, such as bakeries, pasta and rice." The increased variety potentially enhances the accessibility, legitimacy and familiarity of alternative proteins. This provides an opportunity to reconfigure the "images" of alternative proteins amongst the consumers in a manner desirable to the transition, as introduced in the SPT concept.

4.2.3.2 Resource mobilisation

Indicators: Availability of monetary and human capital

As outlined in Chapter 4.2.2.1, governmental grants have been increasingly launched. Concurrently, the governmental agencies (e.g. EDB, ESG) have been building an attractive alternative protein ecosystem to encourage both global and local investment communities to invest in alternative protein technology (R4, R6, R12). However, few roadblocks are observed. First, while more grants are launched, interviewees, notably those in the entrepreneurial sector, disputed that these grants are inadequate and restrictive (as described in Chapter 4.2.2.1). Second, investments in alternative protein are commonly categorised as sustainability investments. However, the mentality that sustainability cannot generate (short-term) profits coupled with the focus on short-term profits remain huge roadblocks in unlocking these investments (R6).

Nevertheless, investor appetite has been picking up following the onset of the "30 by 30" goal and COVID-19 (R5). R10 commented, "It is very hot right now. Even investors in Europe, Silicon Valley and Australia are looking to invest in start-ups in Singapore because of the progressive regulatory environment and the compact market". However, many interviewees (R6, R8, R14, R16) maintained that these investments are usually targeted at high-growth unicorns with a strong base of investors, resulting in a lack of diversification of investments. Besides, the investment cycles are often shorter-term, which does not align with the longer-term goals presented by alternative proteins, thus interrupting "sustainability" objectives, for example, climate change.

"VCs are not very patient, as they want to see the returns on investment as early as possible. For these kinds of infrastructure investments, we would need patient capital that could sit there for 10-30 years, but obviously, there is still quite a risk (to the investors)." (Non-profit organisation - R14).

Moreover, while the investments seem "hot" at the early stages, funding for series C and beyond appears problematic (R4, R10). The funding problems for the later stages appear to be connected with Singapore's inherent flaw – scaling potential (R10, R16). Due to the small market size, it lacks scale compared to the United States and China. Even though Singapore is an excellent hub to launch products for the ASEAN region, each ASEAN country differs culturally in their food preferences. Hence, the launch of products from Singapore into the ASEAN region is unlikely to be exponential. Capital markets in Singapore also tend to be conservative compared to the United States, Europe and Israel (R3, R9). R10 provided an example:

"S$1.5 million is considered a fairly big seed round in Singapore. I cannot think of a single agri-tech VC in Singapore right now who write a S$50 million early-stage cheque. Anything beyond S$1 million is problematic." (Niche entrepreneur - R10).

Regarding human capital availability, agriculture and food production have not been synonymous with Singapore since the 1980s, when local food production declined significantly (CLC, 2018). With a lack of farming history, there is a corresponding dearth of knowledge and interest in agriculture and food production (R5, R7, R10, R11, R12). The food science and technology programmes available at higher education institutes traditionally generate graduates for the labour-intensive food manufacturing industry, which is not recognised as a glamourous industry (R3, R5). As R3 explained, "this is a vicious cycle; the quality of students is not there and, in the end, it is hanging there but not popular". While the government and higher education institutes are looking to enhance the bench strength of food technology, these key actors are also cautious not to oversell their food technology programmes to potential students as the transition to novel foods takes time and the job prospects after graduation are yet to be guaranteed (R3). Both R6 and R8 asserted that most food science and technology graduates are attracted by the salaries and stability offered by public sector research, with few in the small talent pool willing to join private-sector research or start-ups due to their inherent risks.

Fortunately, as technology in the food space advances, boundaries between once-distinctive industries are blurred (R3). Talents from biomedical science and biotechnology industries can apply their skills to R&D in alternative proteins, particularly cultivated protein. Tapping into Singapore's biomedical science and biotechnology expertise provides the city-state with the competitive advantage to nurture the alternative protein ecosystem. Coupled with the well-known governmental push for this industry, foreign talents are increasingly attracted to work in this city-state (R6). However, travel restrictions and the government mandate to consider local hires over foreigners imposed by COVID-19 became a stumbling block in broadening the talent pool in the alternative protein industry (R6).

4.2.3.3 Knowledge development and diffusion

Indicators: Amount of knowledge developed, bibliometrics, horizontal and vertical diffusion of knowledge

The interviewees collectively asserted that the level of knowledge developed in this sector is still in its early stage (R3, R6, R10, R14), in part due to the absence of farming history in Singapore. While there have been mounting resources dedicated to this sector, there is still a lack of human capital as outlined in Chapter 4.2.3.2 to unlock these resources to develop the knowledge rapidly (R12). Nonetheless, Singapore's core expertise in biomedical sciences and biotechnology enables the transfer of these technologies and knowledge to alternative proteins, as discussed in Chapter 4.2.3.1. Whereas for plant-based and insect protein, their learning curves are assessed to be "not so steep […] with ways to come in and learn for beginners" (R7; R5 spoke along the same lines). Therefore, while the knowledge developed for this sector has been nascent so far, there is potential to advance the knowledge further.

Additionally, R8 and R12 contended that the pressure to drive to the commercialisation stage is particularly pronounced in this sector. From an academic perspective, the journey to commercialisation has traditionally been insufficiently detailed in academic journals (R8). As a result, citations are scarce and fragmented, resulting in low impact factors of the academic journals (R8).

Regarding the horizontal and vertical diffusion of knowledge, both appear to be deficient. The interviewees expressed that knowledge tends to be saturated upstream (R1, R3, R5, R6, R8, R10). A gap thus exists between the upstream research and downstream adaptation, in particular for cultivated protein. R8 commented:

"There are a lot of people in the research side working on tissue engineering, regenerative medicine, cells therapy, cells manufacturing side, which are portable to work on this kind of problems for cultivated protein. However, it needs to be tuned and adapted to the specific problems the cultivated protein has, e.g. cost, food grades." (Research and education institute & niche entrepreneur - R8).

A lack of communication and common language and understanding between upstream researchers and downstream food manufacturers possibly contributes to this knowledge gap. The implication of the gap is the lack of context to evaluate whether the technology or solution is indeed helpful for the sector or transition (R8), or the development of technologies and solutions misaligned with consumers' tastes and preferences, thus impeding the adoption of and transition to alternative proteins.

In terms of horizontal diffusion of knowledge, sharing of knowledge amongst researchers and entrepreneurs is currently scarce. R12 pointed out that "most of the (alternative protein entrepreneurs) are still experimenting. So, they will share information and knowledge to experiment and not enough to replicate the products […] increasingly; we will see the knowledge diffusion happening in hiring, poaching, rather than collaboration." While some unique collaborations are occurring in the industry, such as between Shiok Meats and IntegriCulture (R11; IntegriCulture (2020)), R11 emphasised the challenge of sharing knowledge when companies are working on different topics or species (in the context of cultivated protein). R11 also contended that "if they are directly working on the same things, then those people will be protecting their technology from each other." The desire to protect information from each other possibly arises likely because these alternative protein entrepreneurs view each other as competitors rather than collaborators trying to uproot the conventional protein sector. This is perhaps due to the mentality that alternative proteins cannot replace conventional proteins, a mentality commonly present amongst the interviewees (R1, R2, R3, R4, R6, R7, R8, R10). Another possible reason is the eager pursuit of building unicorns – a term in the investment community that refers to high-potential start-ups valued over $1 billion (R8). Venture capital firms, governmental agencies and other investment firms have been pouring enormous funds into start-ups identified with unicorn potential. These start-ups have difficulty digesting the funds since technology and solutions are less ready to deliver (R8). Thus, mergers and acquisitions occur at very early stages as many investors are targeting the few cell sources (for cultivated protein), know-how and available technologies (R8). This impedes sharing since the values of such knowledge are incredibly high.

4.2.3.4 Overall analysis of the strength of niches

Overall, the Likert scale relating to the strength of niches is assessed in Table 14:

Table 14: Likert scale of niches

Indicators	Likert scale[6]	Reasons
N1: Number of new entrants	3	Network anchoring mechanisms and a progressive regulatory environment helped to increase the number of new entrants, but the sector is still considerably nascent.
N2: Breadth of products	3	Breadth is expanding and demonstrates vast potential, but the sector is still nascent.
N3: Breadth of technologies	3	Singapore's expertise in biomedical science and biotechnology presents valuable opportunities to expand the verticals, but a gap still exists between the current stage and the potentials of this sector.
N4: Availability of monetary capital	2	Investments seem "hot" at early stages, but funding for later stages appears problematic.

[6] Scale from 1-5, with 5 being the most favourable for the transition

N5: Availability of human capital	1	Talent pool is insufficient.
N6: Amount of knowledge developed	3	Knowledge developed is incredibly early-stage but demonstrates massive potential for further advancement.
N7: Bibliometrics	1	Drive to commercialisation is pronounced; citations are scarce and fragmented.
N8: Extent of horizontal diffusion of knowledge	2	Horizontal diffusion of knowledge is deficient, with scarce sharing of knowledge.
N9: Extent of vertical diffusion of knowledge	2	Vertical diffusion of knowledge is deficient, with a saturation of knowledge upstream.

4.2.4 Consumers' perceptions and practices

Indicators: Images (Perceived nutritional value, price, environmental impacts, accessibility and taste of alternative proteins vis-à-vis conventional proteins), Skills (Familiarity with substituting conventional with alternative proteins in cooking), Materials (Availability of alternative proteins)

As a socio-technical transition, consumer uptake of alternative proteins is crucial in determining the shifts in the regime. By utilising the Social Practice Theory (SPT), this subchapter analyses consumers' perceptions and practices regarding alternative proteins in Singapore. With guidance obtained from the survey conducted by Thomas and Bryant (2021), which analysed consumers' perceptions and acceptance of plant-based dairy, a survey was performed to analyse consumers' images, skills and materials. Table 15 explains the application of images, skills and materials in the survey.

Table 15: Application of SPT in survey

Aspects of Social Practice Theory (SPT) (adapted from Shove & Pantzar, 2005)	Application in survey
Images	Perceived _____ vis-à-vis conventional meat and seafood: - nutritional value - price - taste - accessibility - environmental impacts
Skills	Familiarity with substituting conventional with alternative proteins in cooking
Materials	Perceived availability of alternative proteins in retail

Although this paper covers fermentation-based protein as the fourth alternative protein category, it is not well-known to survey participants due to its current lack of availability in the market. Hence, fermentation-based protein has been categorised under whole-foods or processed plant-based protein in the survey.

4.2.4.1 Images

This subchapter captures respondents' perceptions of alternative protein types vis-à-vis conventional proteins across five factors (nutrition, price, taste, accessibility and environmental impacts), using a 5-point Likert scale rating. The rating of one corresponds with a negative perception and the rating of five with a positive perception. The respondents were first asked to select the factors that shape their protein choice. 91% indicated taste, 87% indicated price, 79% indicated accessibility, 66% indicated nutrition, 51% indicated environmental impacts and 5% indicated other factors such as habit and religion, as shown in Figure 6.

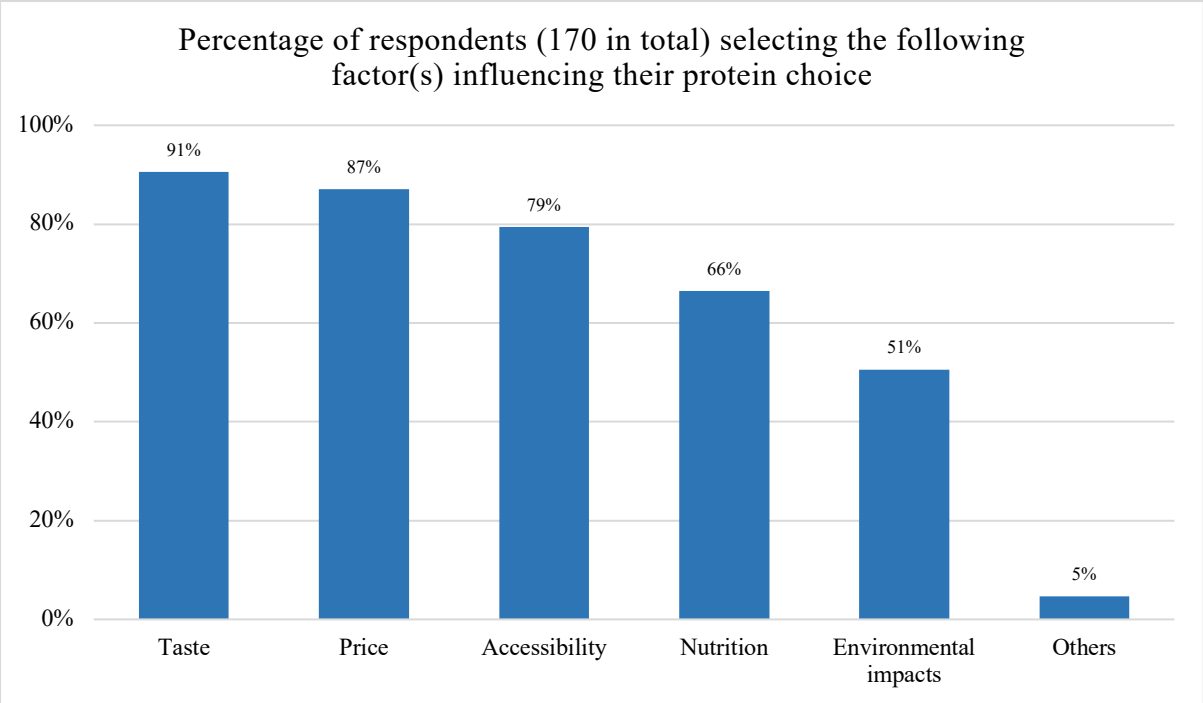


Figure 6: Assessment of factors influencing consumers' protein choices

After selecting the factors influencing their protein choices, respondents were then presented with factor-specific questions investigating the perceptions for the different protein types. The ratings for each protein type (including conventional proteins) across all five criteria are found in Appendix 4.

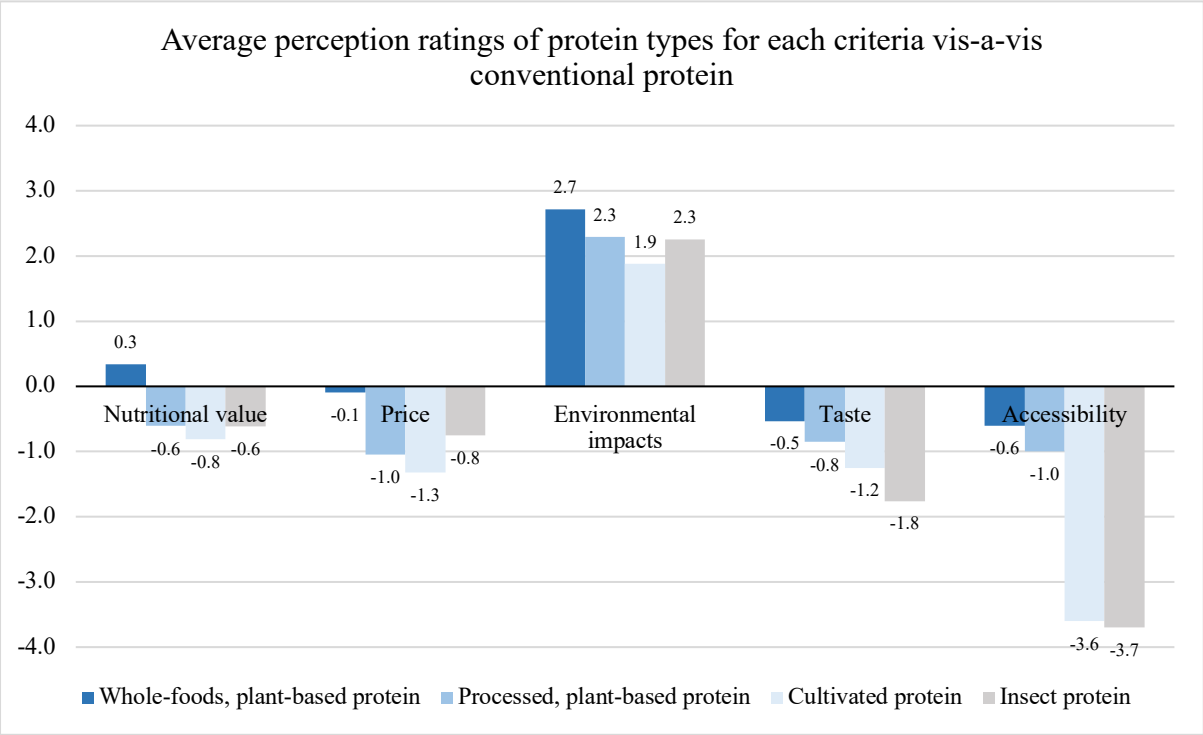


Figure 7: Average perception ratings of alternative protein types vis-a-vis conventional proteins

Figure 7 shows a direct comparison in perceptions between the alternative protein types and conventional proteins, with ratings (based on a 5-point Likert scale whereby five corresponds to a positive perception) of the conventional proteins subtracted from the alternative protein types. This figure illustrates that alternative proteins were perceived as inferior to conventional proteins in terms of price, accessibility and taste. For nutritional value, only whole-foods, plant-based protein was perceived as superior to conventional proteins. All alternative protein types included in the survey exceeded conventional proteins in perceived environmental impacts. Unfortunately, environmental impacts was not the top factor influencing an individual's protein choice, with only 51% selecting environmental impacts, as seen in Figure 6. This can be attributable to the lack of interest or knowledge in the environmental impacts of meat production. Knowledge is necessary for any voluntary changes in actions or behaviours (Bord et al., 2000) and unaware individuals are unlikely to change their meat consumption habits without resistance (Vinnari & Vinnari, 2014). However, even if the consumers have some knowledge, they may not act accordingly with their knowledge (Novacek, 2008), as the tragedy of the commons reigns even at the individual consumer level. Until a crisis happens, environmental problems are viewed as less crucial than, for instance, imminent economic concerns (Vinnari & Vinnari, 2014). As R3 and R6 put, "it takes a crisis (to trigger the switch to alternative proteins amongst the masses)". Taste and price were the most critical factors influencing the protein choices, as seen in Figure 6. However, alternative proteins were perceived inferior in both of these aspects vis-à-vis conventional proteins.

Nonetheless, it is worth noting that the lack of accessibility and sufficient knowledge of cultivated protein and insect protein may have contributed to these ratings. When the accessibility and awareness of both alternative proteins improve in future, the perceived ratings

vis-à-vis conventional proteins may shift. Hence, while it is crucial to understand the consumer perceptions of these protein types to inform actions accordingly, the perceptions are fluid and can be influenced by various factors such as media reports, experiences and word-of-mouth.

4.2.4.2 Skills

73% of the respondents (51% + 22%, as shown in Figure 8) indicated at least some familiarity with alternative proteins to substitute conventional proteins when cooking. However, this level of familiarity did not translate to action as only 17% (9% + 8% as shown in Figure 9) indicated that they substitute meat and seafood with alternative proteins most or all of the time.

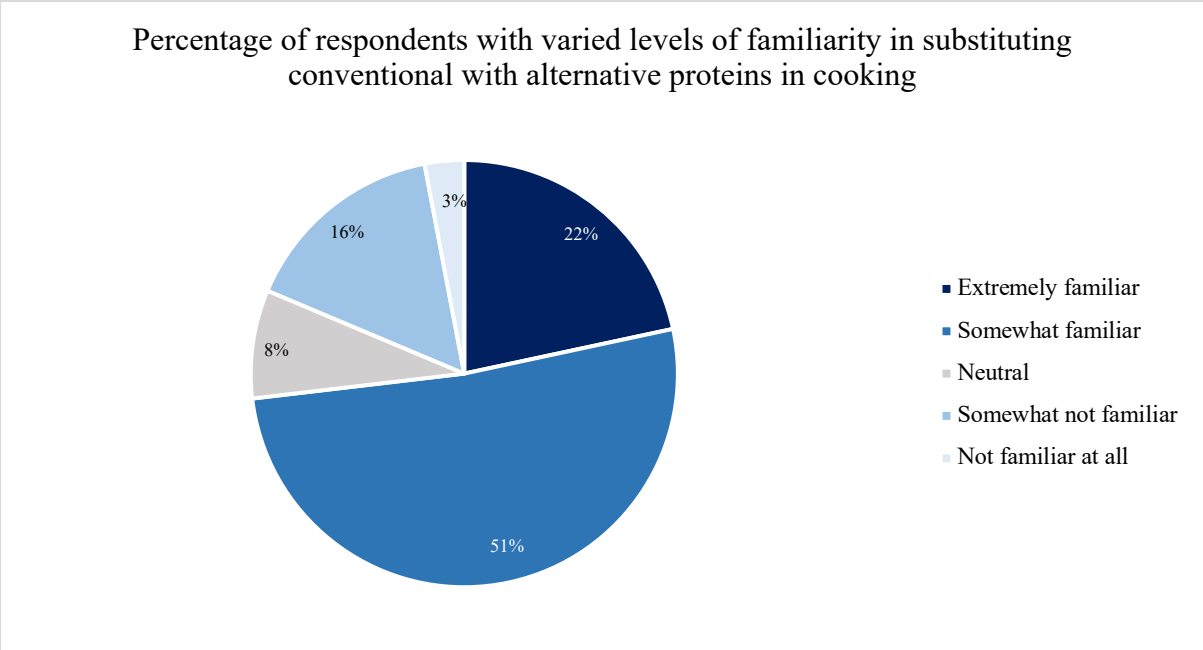


Figure 8: Assessment of familiarity in substituting conventional with alternative proteins in cooking

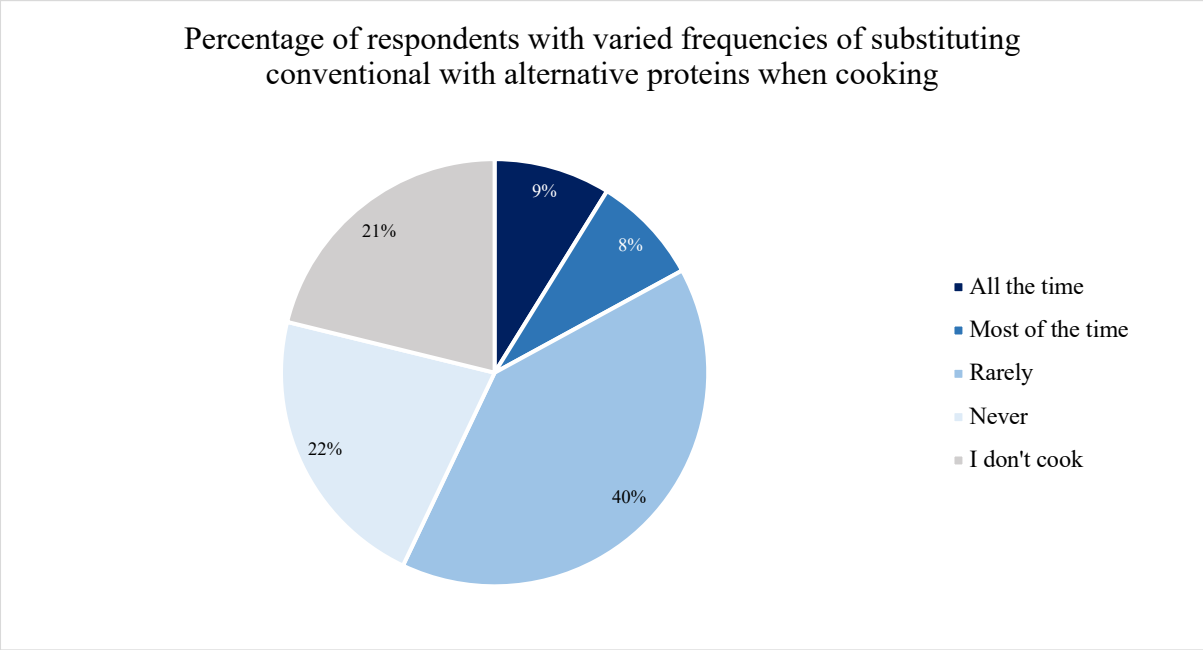


Figure 9: Assessment of frequency in substituting conventional with alternative proteins in cooking

The survey participants mentioned a few critical reasons in the open-ended questions for this behaviour - taste, price, accessibility, and survey respondents are likely to cook for family and friends who are less keen to substitute conventional proteins. As seen in Figure 10, 86% of the respondents indicated that the lack of accessibility of alternative proteins is one of the key factors stopping them from substituting conventional proteins. Price (79%), taste (70%) and social pressure (i.e. having to factor in and adjust to the protein choices of family and friends) (55%) are other important factors as well. The results correspond to Figure 6, which asked the respondents for the factors influencing their protein choice, where taste, price and accessibility were the top factors.

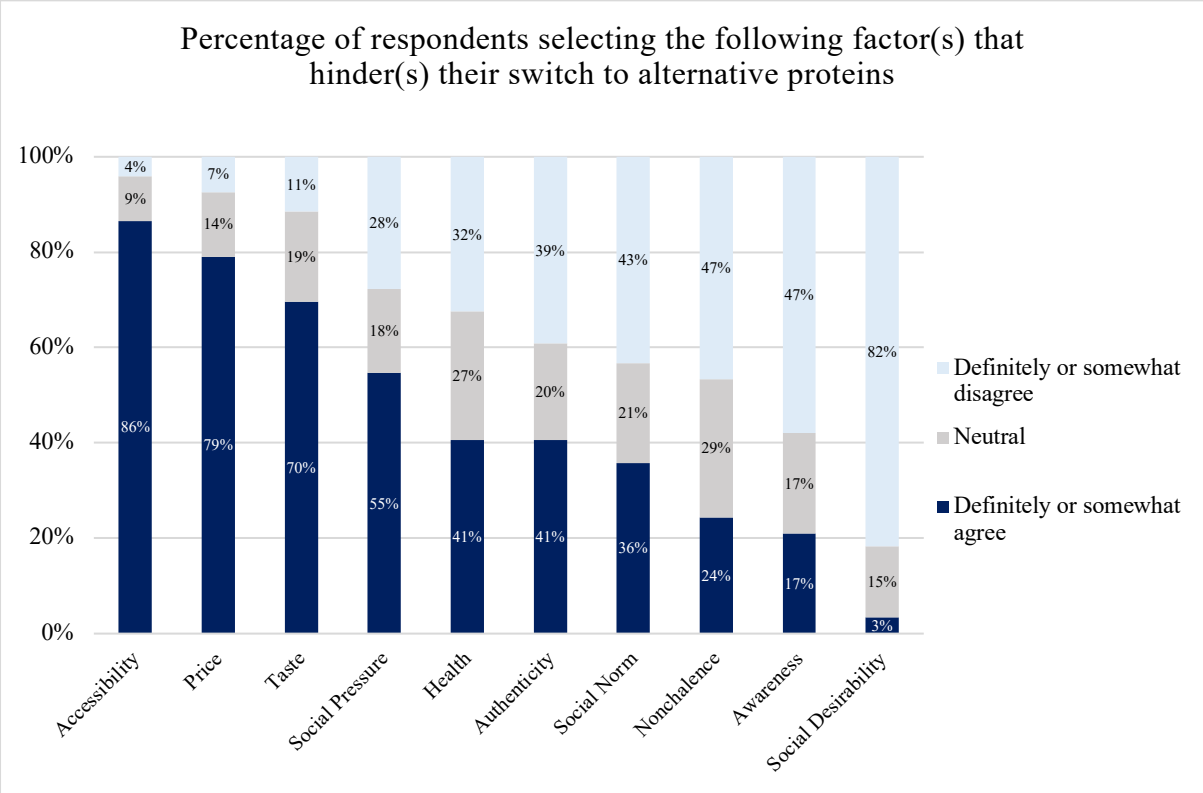


Figure 10: Assessment of main obstacles hindering the switch to alternative proteins

4.2.4.3 Materials

Regarding the perceived availability of alternative proteins, 76% of all respondents expressed that the range has increased in supermarkets (Figure 11). In comparison, 65% noted the increase in food and beverage outlets (i.e. restaurants and local eateries including kopitiams and hawker centres[7]) (Figure 12).

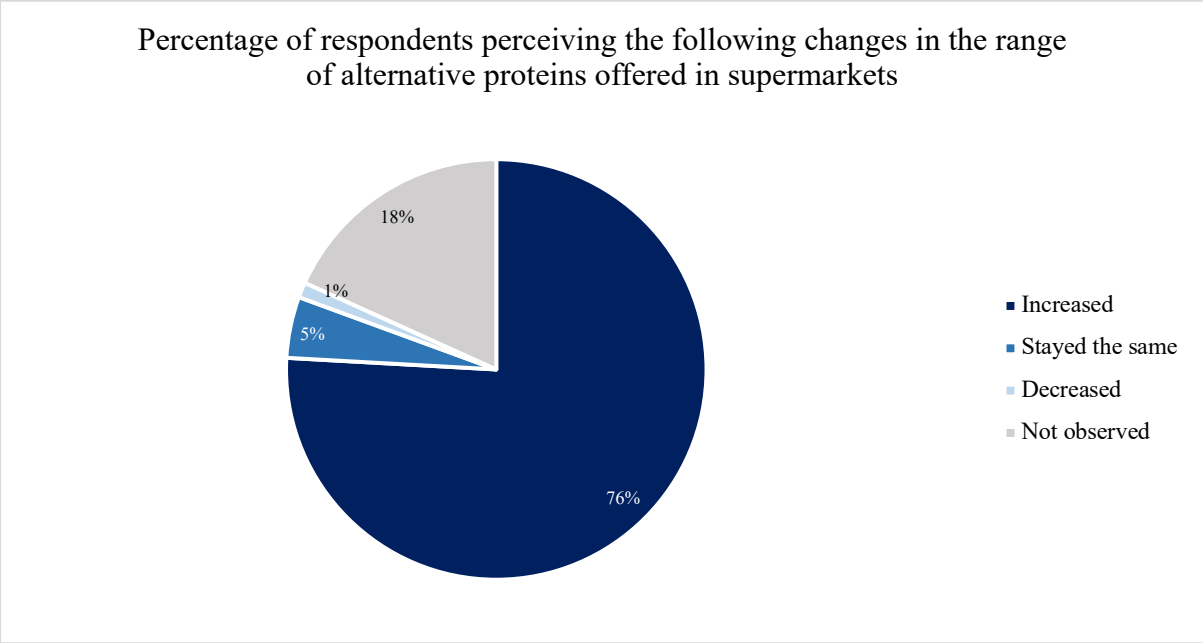


Figure 11: Percentage of respondents perceiving the following changes in the range of alternative proteins offered in supermarkets

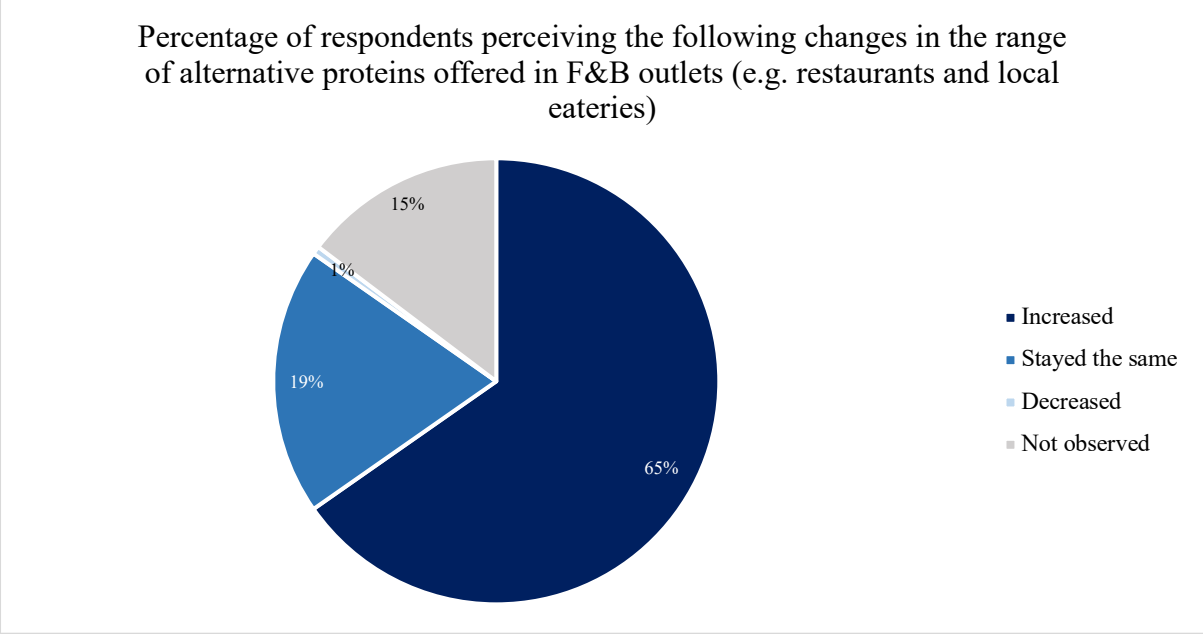


Figure 12: Percentage of respondents perceiving the following changes in the range of alternative proteins offered in food and beverage (F&B) outlets

[7] A hawker centre is an open-air food complex in Singapore that offers highly affordable food and beverages of typically a local flavour. A kopitiam offers a similar concept as a hawker centre, but usually with a smaller selection of food and beverage.

Nonetheless, despite the observed increase in the range of alternative proteins offered, there is still a perceived lack of accessibility vis-à-vis conventional proteins (as noted in Figure 7), which influences the respondent's protein choice accordingly.

4.2.4.4 Overall analysis of consumers' perceptions and practices

While there is a reasonable level of skills and an increased availability observed by the respondents, the key factors influencing the protein choices, price, taste and accessibility, were still perceived to be inferior vis-à-vis conventional proteins. Drawing reference from the example of Eostre Organics, a cooperative that synthesised 16 small-scale producers of organic food, in Hargreaves et al. (2013), the niche was unsuccessful as the "images", "skills" and "materials" demanded by the niche are not aligned with existing configurations at the individual lifestyle level, and thus, failed to spread extensively. Therefore, the perceived inferiority of alternative proteins vis-à-vis conventional proteins in terms of price, taste and accessibility may be the key factors hindering the protein transition, as they are not currently aligned with existing systems of practice and thus may fail to trigger mass adoption.

Overall, the Likert scale relating to the consumer perceptions and practices is assessed in Table 16:

Table 16: Likert scale of consumer perceptions and practices

Indicators	Likert scale	Reasons
C1: Images	2	Alternative proteins are perceived as inferior to conventional proteins in terms of price, accessibility and taste, although they exceeded conventional proteins in environmental impacts. Unfortunately, environmental impacts was not the top factor influencing an individual's protein choice.
C2: Skills	2	73% of respondents indicated some familiarity with using alternative proteins to substitute conventional proteins, but this level of familiarity did not translate to action.
C3: Materials	2	Accessibility of alternative proteins increased, but still poor vis-à-vis conventional proteins.

4.3 Dynamic interactions amongst the levels

The interactions amongst the various levels of landscape, regime, niches and consumers are dynamic and multifaceted. The dynamics mainly arise from the regime's response to pressures exerted by landscape factors, creating openings for niches to break through the regime. In this subchapter, three sets of interactions amongst the levels are discussed, with the help of the co-occurrence table extracted from Atlas.ti as seen in Table 17. Based on this analysis, the transition pathway is deliberated upon in Chapter 4.4.

Table 17: Co-occurrence table

			MLP						SPT		
			Landscape	Regime		Niches (TIS)			Consumers		
			Landscape factors	Political actors' responses	Incumbent actors' responses	Entrepreneurial activities	Resource mobilisation	Knowledge development and diffusion	Images	Skills	Materials
MLP	Landscape	Landscape factors		14	3	13	14	10	3	0	0
	Regime	Political actors' responses			10	15	15	12	2	0	0
		Incumbent actors' responses				5	0	0	0	0	0
	Niches (TIS)	Entrepreneurial activities					4	4	7	0	7
		Resource mobilisation						4	4	0	5
		Knowledge development and diffusion							1	0	0
SPT	Consumers	Images								2	4
		Skills									1
		Materials									

Table 17 illustrates the number of intersecting quotes between the variables that appeared in the interview transcripts. A higher number, indicated by a deeper shade of green, shows a greater extent of co-occurrence and interaction between the variables. Therefore, from Table 17, three significant sets of interactions are observed – (1) landscape factors and regime, (2) landscape factors, regime and niches, and (3) niches and consumers.

(1) Landscape factors and regime

Climate change, COVID-19, food security, priority on health and the growing environmental and ethical concerns of animal agriculture are landscape factors exerting pressure on the meat production regime, generating opportunities for niches to break through. This is evident in Singapore, where political actors are responding to the pressure through implementing strategies targeted at nurturing the niches and fostering the ecosystem, which explains the high co-occurrence between landscape factors and political actors. The agricultural-neutral context of Singapore enables the political actors to extend firm support to the niches, thus explaining the high co-occurrence between political actors' and incumbent actors' responses.

(2) Landscape factors, regime and niches

Niche entrepreneurs are responding to the gaps in the regime that are forced apart by the landscape factors by providing an alternative diet that seeks to alleviate the environmental impacts of the animal agricultural system while enhancing food security. The support from the political actors in Singapore nurtures and shields the niches against some of the prevailing selection pressures in the regime, thus explaining the high co-occurrence between political actors and niches. While empirical studies in sustainability transitions literature tend to illustrate the resistance from the regime towards niches, this empirical case study is challenging the theory. The resistance from the regime in transitions literature commonly exists in two broad forms – opposition from regime actors and regime rules which lead to lock-ins and path dependencies. In this case study, the former type of resistance is less applicable. Political actors are actively supporting the niches as it is aligned with their vision of enhanced food security. In contrast, the agricultural-neutral context of Singapore means that meat producers and food processing companies do not have much political or economic power to resist the niches. The second type of resistance – regime rules is significantly more evident in this case study. Table 18 illustrates the differences in the regime and niche rules:

Table 18: Differences in rules between the regime and niches

Types of rules (El Bilali & Probst, 2017)	**Regime**	**Niches**
Regulative rules (Laws, standards & policies)	- Food safety laws - National strategy on Anti-Microbial Resistance aligned with World Health Organisation's One World Approach (SFA, n.d.-c) - Animals and Birds Act (2019) (Act to prevent animal diseases from entering into and spreading within Singapore and to protect the general welfare of animals)	- Food safety laws, particularly for novel foods, e.g. Novel Food Regulatory Framework mandates companies to seek assessments and approvals for novel foods. (SFA, n.d.-b)
Normative rules (Values and discourse	- Upholding of traditions and cultures to eat meat (Vinnari & Vinnari, 2014) - Abiding by social norms to avoid exclusion (Vinnari & Vinnari, 2014) - Social bonding around meat consumption (Vinnari & Vinnari 2014, p.381) - Meat is an essential protein/nutrient - "Meat is medicinal" (R6) - Eating is an enjoyment of life and there should be no restriction on food choices - Animals are placed on earth for our consumption (Vinnari & Vinnari, 2014)	- Heavy meat consumption is a contemporary trend and not part of traditions and culture - To build social bonding around alternative proteins instead - Meat is not an essential nutrient/protein - Neither is it medicinal - Eating within planetary boundaries is a way of enjoying life - Animals are neither placed on earth for humans' consumption nor are they inferior to human beings
Cognitive rules (Guiding principles on problem definition)	- Beliefs in efficiency, productivity and profits and keeping food prices low - Short-term perspective; short-term profits are a priority - Concerns about the economic welfare of meat producers - Lack of awareness between the food system and environmental impacts, or interest to address the issues	- Social and environmental aspects should be equally prioritised - Long-term perspective; sustainability is essential to the survival of businesses and humans - Providing meat producers alternative revenue streams while phasing out conventional animal agriculture - Awareness between the food system and environmental impacts, with interest to address the issues

These regime rules create selection pressures that disadvantage the alternative protein niches as the niches might demand too many socio-technical changes (Smith & Raven, 2012). For example, entrenched cultural meaning attached to meat consumption forms a selection pressure that demerits alternative proteins because the latter epitomises different cultural values. Current institutional structures, such as current capacities and processes for resource allocation, price mechanisms, consumer preferences and customs, also empower conventional meat consumption (Smith & Raven, 2012). Initial protection is thus vital because niches cannot successfully compete with the selection pressures embedded in the incumbent meat regime. While the political actors actively attempt to protect the alternative protein sector against some of the selection pressures, these attempts have often been targeted at nurturing the niches, with little regard for the regime rules. Excessive focus on niches can also inadvertently reinforce lock-ins, diverting actions away from regime transformation (Geels, 2014; Kuokkanen et al., 2018). Except for regulative rules, normative and cognitive rules of the regime would likely continue to take precedence.

(3) (Regime), niches and consumers

The empirical case study of EcoTeams by Hargreaves et al. (2013) highlights that efforts to reconfigure practices may be hindered by the broader structures and systems embedded in the regime. Therefore, in addition to understanding the configurations in consumer practices, there is a need to attend to the intersection points between the regime and practices to acquire crucial knowledge of processes obstructing sustainability transitions (Hargreaves et al., 2013). Consumers in the survey reported fundamental obstacles in the broader systems and infrastructures that hindered their consumption of alternative proteins over meat - prices, accessibility, lack of knowledge with regards to cooking alternative proteins, observance to social norms to eschew exclusion, lack of education regarding the environmental impacts of food systems and opaque agri-food practices, amongst other factors and meat consumption fitted-in to everyday foods. In this regard, analysing the intersection points between the regime and practices exposes the elusive and implicit ways they are locked in and locked together (Unruh, 2000). Therefore, strategies to reconfigure practices must consider these intersection points or risk being rendered ineffective upon encountering the ostensible obduracy of the broader systems that espouse the status quo (Hargreaves et al., 2013). However, as observed from the interviews (R3, R4, R6, R9, R10, R11, R12, R14), strategies from the regime have not paid sufficient attention to these intersection points, thus explaining the low or nil co-occurrence between the regime and consumer practices. Entrepreneurial activities seek to reconfigure the “images” and “materials” in a more desirable manner (illustrated by the moderately high co-occurrence between entrepreneurial activities and consumer practices). However, the widely intact regime rules remain as critical obstacles in reconfiguring the practices.

4.4 Regime shift: type of transition pathway

Indicators: Timing of interactions, nature of interactions, adjustments in regime

According to Geels and Schot (2007), climate change is typically viewed as a moderate change by actors due to its gradual process. Food systems, particularly meat production, have been a contributor to climate change and a recipient of its impact for a long time. However, the pace of climate change has been too gradual and slow to trigger adequate actions by the regime actors. With limited local food production, Singapore's primary food strategy has been diversifying food supplies from various countries with little control over agricultural practices abroad. Apart from climate change, other landscape factors, such as increasing health and animal welfare concerns, pressure the regime. Outside criticism first came from niche entrepreneurs who developed alternative protein products and drew attention to the externalities of meat production typically disregarded by regime actors (van de Poel, 2000, 2003). However, little action was taken by the regime actors in the past as these concerns were superseded by other seemingly more imminent issues like economic priorities. Little recognition was given to niche entrepreneurs.

Nonetheless, this changed since the onset of the "30 by 30" goal and the COVID-19 pandemic. Singapore's food security was further threatened. The demonstration of the feasibility of alternative proteins in contributing to food security, particularly in cities with land constraints, progressively altered the perceptions of regime actors. Reorientation of activities, clustered under the "30 by 30" goal, to nurture these niches ensues. As such, the legitimacy of alternative proteins has only recently increased. The implication is that the niches are underdeveloped. This is evident by the high price-performance ratios of the alternative proteins, particularly for the recently introduced protein types such as cultivated protein and processed, plant-based protein (e.g. Impossible Foods patty priced higher than regular meat patties). Therefore, landscape pressure is occurring at a time when the niches are still underdeveloped (Geels & Schot, 2007).

Many interviewees (R1, R2, R3, R4, R6, R7, R8, R10) expect alternative proteins to complement the current meat sector rather than fully replace it, partly due to the difficulty to convince people to replace meat completely. As the niches are still underdeveloped, there is time for the regime to reconfigure itself and react to the changes in the food system by adopting alternative proteins. For example, incumbent companies, both meat manufacturers and food processing companies, have also been investing in alternative proteins by acquiring niche entrepreneurs, partnering with them or innovating independently. Examples include Tyson Foods, Cargill, Nestle, Unilever, local food processing company Tee Yih Jia (R2; Sexton et al., 2019; Quek, 2021). Therefore, symbiotic relationships between the niche innovations and the regime are observed as the former is gradually adopted into the existing regime (Geels & Schot, 2007). These adoptions are driven by various considerations. One primary desire of the incumbents is the motivation to benefit strategically from the growing economic potential of niche innovations. As the existence of incumbent companies is unlikely to be threatened by

alternative proteins, particularly with their growing adoption of niche innovations, most regime rules may remain unchanged.

Hence, the transition pathway currently occurring is "Transformation", as moderate landscape pressure is occurring at a time when the niches are still underdeveloped (Geels & Schot, 2007). In this path, reorientations and adjustments result in new regimes developing from old regimes (Geels & Schot, 2007). Incumbent companies are likely to survive so long as they remain updated with consumer preferences. They may adopt knowledge from the niches if it is not too radical. Symbiotic niche innovations are gradually embraced within the regime without disrupting its basic architecture, except for a few adjustments:

- *Infrastructure and business models*

  The survey respondents observed a growing number of restaurants and supermarkets incorporating plant-based options, although the options offered in each establishment are notably limited. Local food processing companies such as Tee Yih Jia have also announced their plant-based food line. On the other hand, the wholly-owned subsidiary of SATS[8], Country Foods, distributes sustainable plant-based proteins from a broad range of alternative protein start-ups to its networks (SATS, 2019). The adoption of these niches into the business models and infrastructure is one of the first adjustments noted.

- *Regulative rules in the regime*

  Food safety laws developed for alternative proteins are increasingly entrenched in the regime, such as the Novel Food Regulatory Framework, which mandates companies to seek assessments and approvals for novel foods (SFA, n.d.-b). Network organisations working towards improving the regulative rules for niches, such as the Future Ready Food Safety Hub (FRESH) launched in April 2021 (MSE, 2021), are also one of the few adjustments observed.

As the niches are still in their infancy stage, not many adjustments have been observed in the regime. However, as landscape pressure intensifies and political support strengthens further, more adjustments in the regime may emerge. A series of transition pathways may thus ensue, starting with "Transformation" and then "Reconfiguration". "Reconfiguration" is similar to "Transformation" in that niche innovations possess a symbiotic relationship with, and are adopted into, the regime (Geels & Schot, 2007). However, under "Reconfiguration", further adjustments materialise in the regime (Geels & Schot, 2007). These adjustments may include:

- *Market share*

  All interviewees, including governmental actors and research and education institutes (R1-R16), are optimistic about the long-term growth of the alternative protein sector. However, while the government provides firm support, many hurdles can impede its share of the protein market vis-à-vis conventional proteins. For example, several interviewees (R5, R6,

[8] Established in Singapore, SATS is one of Asia's largest providers of Food Solutions and Gateway Services (SATS, 2019)

R10, R11) expressed their concerns about driving the prices down to competitive levels, mainly due to the low yield produced by current technologies or the lack of infrastructure. Prices that cannot compete with conventional proteins will affect its accessibility (as downstream partners such as hawker centres will not switch to alternative proteins). The coupling of both price and accessibility factors will also impact consumer uptake. With price and accessibility being the crucial drivers behind consumers' protein choice (as shown in the survey results) and the continued increase in consumer demand for meat protein (Organisation for Economic Co-operation and Development [OECD] and FAO, 2021), it is therefore difficult to estimate the share of the protein market that niches could achieve.

- *Consumer bases*

  What started from religious groups, environmentalists and animal welfare advocates could develop into mass adoptions amongst consumers if the perceived price, accessibility, taste and nutrition of alternative proteins improve compared to conventional proteins. However, while taste and nutrition can strengthen through continuous experimentations, consumer feedback and education, there are more hurdles beyond the control of the entrepreneurs to enhance the cost-competitiveness and, consequently, accessibility of alternative proteins. Those factors are mentioned above under market share. If successfully overcome, alternative proteins can become regular proteins in consumers' diets. Otherwise, they will remain as niches.

- *Normative and cognitive rules in the regime*

  As mentioned in Chapter 4.3, normative and cognitive rules remain mostly unchanged under the current regime, unlike regulative rules. The widely unchanged rules are primarily due to a lack of consumer awareness and institutional structures that continue to empower meat consumption. If consumer education and the range of viable consumer options strengthen, the normative and cognitive rules could reconfigure gradually in favour of the niches. However, the period for adjustment of the rules is difficult to assess. It depends on various factors, such as the aggressiveness of the consumer education strategies put forth by the regime and niche actors and how well-received these strategies are.

Geels (2018) postulates that a socio-technical transition involves modifications in technological and social aspects, including cultural meanings, policies, consumer practices, business models and infrastructure. While the transition started with the promise of the technology in alternative proteins contributing to Singapore's food security, "social" changes first occur with the changes in policies (e.g. cultivated meat approved for commercial sales in Singapore) and then in infrastructure and business models. However, it is currently unclear whether actual social changes can occur in consumer practices and cultural meanings.

4.5 Discussion of findings

Interpretations and implications of findings

This case study has elucidated the factors that obstruct and impact the directionality of the transition. The alternative protein sector is nascent and, understandably, some indicators are not performing strongly yet – such as the breadth of technologies, knowledge and products developed. However, some indicators, such as funding and knowledge diffusion, present more significant obstacles to the transition. Although there is a recent increase in funding, the interviewees often described it as inadequate, restrictive or myopic. Myopic funding, which expects quick returns, does not align with the longer-term goals presented by alternative proteins, thus interfering with the core principles of sustainability. Such funding might compromise research and development and the ability to obtain a desirable yield, particularly for cultivated protein, which is currently too low to bring prices down to a competitive level. Nonetheless, as in other cases, over-dependence on external funding without a self-subsisting business model could threaten the business's going concerns once the funding period has ended. On the other hand, uneven knowledge diffusion amongst industry partners and throughout the value chain may result in inefficient use of resources, e.g. when actors are researching the same topic, thus decelerating the transition. These obstacles have several implications on factors key to consumer adoption, such as price and accessibility.

Furthermore, although the "30 by 30" goal has enabled the mainstreaming and nurturing of the alternative protein niches, little attention has been paid to the cognitive and normative rules entrenched in the regime. Consequently, regime rules remain largely intact, resulting in lock-ins on routines and practices favouring conventional proteins. The preservation of regime rules is also attributable to the preference of the regime, including the political actors, to uphold its dominance by favouring incremental alterations to solve regime issues (Ingram, 2015). The political vision of enhancing food security, which does not seek to diminish meat consumption but rather provide more protein options to consumers and allow "market forces to shape one's protein choice" (R12), means an incremental process of diversifying protein options naturally follows. The rationale behind that, explained by interviewees in the governmental sector, is the governmental inability to influence consumer behaviours regarding food consumption. Considering Singapore's track record of social engineering efforts to nudge residents into the desired behaviour (Detenber, 2021), successful government intervention in the form of nudges seems possible.

A relevant example is the "Frozen Pork is Just as Good" campaign in 1985 which nudged residents into choosing frozen over fresh pork (CLC, 2018). This campaign emanated from the desire to encourage consumer adoption of frozen pork as local pig farms were being phased out and pork sources had to be diversified (frozen, chilled and fresh) (CLC, 2018). Similar nudges to encourage consumer adoption of alternative over conventional proteins could be done, but the intervention seems to occur only when significant disruptions in food supplies are anticipated. Otherwise, it appears more politically feasible to support the innovation and diversification of protein options than to promote a reduction in meat consumption and

production (Tziva et al., 2020). The risk is that normative and cognitive rules remain centred on conventional proteins, making it challenging for consumers to make the switch. As a result, although alternative proteins could be incorporated into the business models as additional revenue streams, many regime actors (such as local food processing companies) have chosen a hesitant "wait-and-see" approach, thus limiting the accessibility of alternative proteins in the market. Even though the niches demonstrate high potential for growth due to solid support and legitimation bestowed by the authorities, the sector is incredibly nascent. Thus, the niches are currently limited in their ability to impact the regime rules. Therefore, the "Transformation" path is likely to be advocated until a major crisis emerge, as imminent issues such as economic, food security and COVID-19 concerns are prioritised over long-term matters like climate change. As R3 and R6 put it, "it takes a crisis" before more radical transitions to alternative proteins can be observed.

Considering Singapore's hegemonic regime (Ng, 2018), the political vision of food security is likely to spill over to niche entrepreneurs. Järnberg et al. (2018) caution that although this enables the impact of the niches to be more wide-reaching, tradeoffs that undermine their sustainability potential could emerge. Tradeoffs include the development of alternative protein niches that adapt to a primarily unchanged regime (Smith & Raven, 2012). As a result, the transition and changes become incremental rather than radical (El Bilali, 2019b). However, the complexity and interconnectedness of the wicked problems in current food systems mean that incremental changes are inadequate (STRN, 2010). For example, hybrid meat products, i.e. part meat and part plant (Grasso & Jaworska, 2020), are developed to fit the relatively unchanged regime rules. These alternative protein niches may have started as radical but subsequently become incremental to compete on the socio-economic criteria of incumbent markets (Smith & Raven, 2012). Consequently, the desirable environmental impacts of the niches may be reduced through this need to fit and conform. Therefore, this begs the question of whether the transition is truly environmentally sustainable. Markard and Truffer (2008) lament that the normative aspects of sustainability are insufficiently elucidated in sustainability transitions literature. Hence, this paper has shown the need to include an elaborate discussion on the normative concepts of sustainability and an assessment of the aspects of sustainability through indicators such as life cycle analysis and economic cost-benefit analysis in future research.

Another implication of this paper is the emphasis on using the selected transitions frameworks in tandem and on analysing the intersection points between the regime and practices, as underscored by Hargreaves et al. (2013). The central hypothesis of MLP is that landscape changes create pressure in the regime, which generates opportunities for niches to break through, whilst the regime is often depicted as a source of resistance against the niches (El Bilali, 2019b). However, in this empirical case study, the regime (i.e. the progressive authorities and almost-powerless incumbent companies) drives the transition. Nevertheless, the extent of the transition remains questionable as regime rules remain largely unchanged. Therefore, this shows that any attempt to analyse the transition using the frameworks in isolation can be short-sighted. The same applies to the TIS framework. Although the TIS framework offers a comprehensive assessment for analysing the strength of innovations, it is

inward-looking and inadequately considers the broader environment (Markard & Truffer, 2008). Isolated use of TIS theory would thus be insufficient to underscore the interactions between the broader environment and internal system dynamics that endogenously contribute to the progress of alternative proteins.

Limitations of this paper

Nonetheless, while this paper is value-adding to existing transitions knowledge and provides both practical and theoretical implications, it has some limitations to consider. Although interviews were conducted with diverse actors, incumbent companies, such as local meat producers and food processing companies, were not interviewed due to their lack of response to the interview requests. Correspondingly, their perceptions of the alternative protein sector were not factored in, and the research relied upon desk research and interviews from other actors to analyse this actor group. Thus, some essential aspects and arguments from incumbent companies that drive or hinder the transition might not be adequately represented in this paper.

Additionally, the data analysis has been based on the interviewees' perceptions and personal experiences. It is thus plausible that some notions are allocated more weight than necessary, for example, due to the skewing of data by the interviewees in a direction that suits them best. For instance, the adequacy of government funding could be under-or overstated by the interviewees in the hopes of conveying a message that serves their interests. This could have led to the contrasting views between interviewees in the governmental and non-governmental sectors identified under Chapter 4.2.2.1.

Survey results might also be limited in their accuracy as the responses may not accurately reflect the consumers' intentions and behaviours. Lack of knowledge of and accessibility to certain alternative protein types might also affect their perception ratings, which might change in future once knowledge and accessibility improve. Hence, preferably regularly, ethnographic research should be conducted to assess consumers' perceptions of alternative proteins more accurately. This helps to attend to the intersection points between the regime and practices more effectively.

Integration of MLP, TIS and SPT in the conceptual framework has proved beneficial in grasping unique insights into the key actor groups and their corresponding dynamics. However, frameworks like MLP and TIS were developed in the past and, thus, might be inadequate in addressing contemporary developments such as the recent surfacing of new actors groups. For example, the research has interviewed actor groups like Big Idea Ventures (BIV) and Innovate360, which do not appear to fit in any of the three levels in MLP. Accelerators like Big Idea Ventures (BIV) link the regime and niches together, whereas Innovate360, a start-up spun out from an established company in sugar manufacturing, aims to provide resources abundant in the regime to the niches. These contemporary developments are not included in the sustainability transitions frameworks and thus, not analysed in depth in this research. Hence, future research should consider revisiting the frameworks and adapting them to contemporary phenomena.

Chapter 5: Conclusion

The main research objective is to assess the transition to an alternative protein food system in Singapore through analysing the interactions between landscape factors, regime actors, niche innovation and consumers. A theoretical test of the applicability of the conceptual framework has been performed based on an amalgamation of the MLP, TIS and SPT frameworks in Chapter 2. A diet based on alternative proteins has been globally advocated based upon a promise of reduced environmental impacts while helping to nourish the swelling world's population. On the other hand, Singapore has recognised alternative proteins as an essential contributor to its food security, given the less space required for production. This recognition commenced since establishing the "30 by 30" national goal, which targets to generate 30% of the city's food needs locally by 2030 within its land constraints (Lim, 2021). Since then, governmental support has been pouring into this space which helps to drive the transition. Theoretically, the landscape factors exerting pressure on the regime and the strong support from powerful regime actors would force a regime shift towards a sustainable path. Empirically, this is not (yet) the case in the alternative protein sector in Singapore. The empirical study conducted revealed vital factors hindering the transition despite these drivers. Therefore, this chapter aims to answer the main question, "What is the influence of the key driving and hindering factors on the transition to an alternative protein food system in Singapore?". An elaboration of how this research adds to existing knowledge and compares with the conceptual framework developed in Chapter 2 ensues. The chapter closes with recommendations for future research.

Response to the main research question - "What is the influence of the key driving and hindering factors on the transition to an alternative protein food system in Singapore?"

With food security threatened by several landscape factors, including COVID-19 and climate change, Singapore recognises alternative proteins as an essential contributor to its food security. Therefore, the Singapore government has launched several linking mechanisms to nurture the alternative protein niches and shield them from prevailing selection pressures embedded in the current regime. Network anchoring mechanisms, for example, have blossomed the alternative protein ecosystem, attracting both incumbent companies and entrepreneurs to establish themselves in Singapore, whether it is with regards to setting up innovation centres or businesses. A cautious yet progressive regulatory system is developed, positioning Singapore as the world's first to approve the commercialisation of cultivated meat and further attracting cultivated protein start-ups from abroad to establish in Singapore. As Singapore is an "agricultural-neutral" city-state with little local agriculture and meat production, the government can extend as much support as desired to the niches without incurring resistance from the incumbent meat producers and food processing companies. These linking mechanisms developed by the regime facilitate niche-regime interactions (Elzen et al., 2012), which enables "bricolage", i.e. the assimilation of heterogeneous rudiments and collaboration between distinctive actors desiring to nurture the transition (Feyereisen et al., 2017). However, El Bilali et al. (2019b) warn that transition through "bricolage" thinking becomes a learning-by-doing process, whereby changes are incremental rather than radical.

The implication is that efforts are targeted at mending the gaps in the regime, for example, supporting the niches wherever deemed fit but leaving most regime rules unchanged. Values, discourse and guiding principles remain centred on meat consumption, making it challenging for consumers to make the switch. It is perhaps the reason why although incorporating alternative proteins could be a good business opportunity for local food processing companies, many have chosen a "wait-and-see" approach, thus limiting the accessibility of alternative proteins in the market.

Additionally, linking mechanisms established by the authorities enable knowledge exchange and mutual learning between the regime and niches. Theoretically, this should facilitate the development of shared visions, for which the visions are increasingly embedded in public policies (thus a more bottom-up approach). However, empirically, the vision ("30 by 30" goal) was set and communicated by the authorities, to which the policies are developed accordingly to nurture the niches (a more top-down approach). An over-emphasis on the production of alternative proteins to forcibly meet food security targets without carefully considering consumer uptake in a landscape where regime rules remain primarily unchanged could lead to sustainability problems such as food waste. Even though cultivated protein may satisfy food security in limited land space, it may not be climatically superior to animal agriculture as its environmental impacts heavily depend on the energy demands of its production (Lynch & Pierrehumbert, 2019).

Though mounting regime support has been established to strengthen the functional dynamics of the innovation system, the legitimation provided is incredibly recent, and the strength of the innovation system is therefore still in its infancy stage. Nonetheless, the functional dynamics, assessed through entrepreneurial activities, resource mobilisation, knowledge development and diffusion, demonstrate vast growth potential. New entrants are entering the ecosystem in Singapore, in part due to the governmental efforts in attracting these players. The breadth of technology and products and knowledge development demonstrate growth potential, particularly when knowledge and technology from Singapore's expertise in biomedical science and biotechnology are transferrable. However, this faces obstacles such as restrictive, limited and myopic funding incongruent with the longer-term perspectives needed in developing this sector. The talent pool is also small, as the local food manufacturing industry has not been glamorous in attracting local talent. While efforts have been targeted at overcoming these obstacles, they seem to be saturated upstream, with insufficient attention paid to closing the knowledge gaps between upstream and downstream actors. Hence, the current infancy stage of the niches means that they are not yet well-developed to destabilise the regime or close the gaps in the regime created by landscape factors.

The implications of the above are evident in a few factors key to triggering consumer switch to alternative proteins - price, accessibility and taste (demonstrated by the survey results and interviews). Restrictive, inadequate or myopic funding might compromise research and development and the ability to obtain a desirable yield, particularly for cultivated protein, which is currently too low to bring prices down to a competitive level. Scaling up of alternative proteins is also problematic due to the lack of physical infrastructure, small talent pool and

meagre market size deemed too undesirable for investors and producers to invest. While the protein demand in Asia is expected to grow, the sizeable variety of cuisines and taste preferences in this region means that scaling up exponentially is challenging. The breadth of products and technology is also not sufficiently developed to satisfy the familiar taste and variety of meat products consumers currently obtain from their meat-based diet. Consequently, mass adoption amongst consumers is not yet observed, as perceived prices, accessibility and taste of alternative proteins are still inferior on top of the primarily unchanged regime rules, which results in an incognisance to why a switch is desirable.

Hence, the type of transition pathway is currently "Transformation", as moderate landscape pressure is occurring at a time when the niches are still underdeveloped (Geels & Schot, 2007). As the niches are still in their infancy stage, there has not been many adjustments in the regime, including the regime rules, market share and consumer groups. However, as landscape pressure intensifies and political support grows further, architectural adjustments in the regime may emerge. A series of transition pathways may thus ensue, starting with "Transformation" and then "Reconfiguration". Nonetheless, efforts to boost uptake of alternative proteins must consider the regime rules or risk being frustrated by the obstinacy of the existing regime (Hargreaves et al., 2013).

Comparison with the conceptual framework and contribution to existing knowledge

From the empirical results, it is possible to conclude that the framework combining elements from MLP, TIS and SPT is applicable for understanding the factors affecting the transition to alternative protein food system, despite its shortcomings. It enables a holistic view of the transition and identifies factors driving and hindering the transition, which assists policymakers in prioritising interventions for developing innovations in alternative proteins.

However, agri-food transition research in the literature tends to adapt from the MLP its weak empirical operationalisation of the three levels. Each of the frameworks MLP, TIS and SPT, if solely used in isolation, is also myopic. Hargreaves et al. (2013) argue to attend to the intersection points between the regime and practices, and this empirical case study has demonstrated the need for that. As such, this research extends the current body of knowledge by offering a framework amalgamating these crucial perspectives and attending to the intersection points between the regime, practices and innovation systems. Integrated operationalisation of the elements therein also strives to attune to the intricacies of sustainability transitions and the uniqueness of the agri-food system - deemed value-adding and essential by various agri-food transitions scholars, including El Bilali (2019b).

The threats to the sustainability potential of the transition illustrated in this research also support Markard and Truffer (2008)'s argument for stronger elucidation and analysis of sustainability concepts in sustainability transitions literature. Sustainability is a normative concept – what is perceived by one to be sustainable may be disagreed with by another. While El Bilali (2019b, p.14) highlights that the "impact of transition is related to whether the niche succeeds in solving the pressing problems that lead to its emergence", the perception of the

pressing problem can differ between actors. In this empirical study, the vision of the more powerful actors (i.e. the authorities) spills over to the niches, which may threaten the sustainability potential of the niches. For instance, Audet et al. (2017) showed how the pursuit of food security (particularly via intensifying food production) might emasculate sustainability transition efforts. Hence, this paper reinforces the need to discuss sustainability concepts in transitions research and identify factors that could potentially undermine the sustainability potential.

Recommendations for future research

Future research can thus benefit from the integrative and operationalisable framework offered in this paper whilst combining it with an elaborate discussion on the normative concepts of sustainability and an assessment of the aspects of sustainability through indicators such as life cycle analysis and economic cost-benefit analysis. The findings will provide a thorough analysis of the drivers and obstacles and scrutiny into the sustainability impacts and directionality of the transition.

Additionally, Chapter 4.5 highlighted that revisiting the transitions frameworks to adapt them to modern phenomena is recommended, particularly as contemporary developments emerge. Ethnographic research on consumers should also be regularly conducted to analyse their "images", "skills" and "materials" of alternative proteins vis-à-vis conventional proteins. The findings would aid the development of more effective strategies to reconfigure social practices in a manner congruent with the goals of a sustainability transition.

Lastly, as mentioned in Chapter 2, Geels (2018) postulates that socio-technical transitions include modifications in both technological and social aspects, such as cultural meanings, policies, consumer practices, business models and infrastructure. Chapter 4.4 illustrates some changes in the regime. However, whether actual social changes can occur in consumer practices and cultural meanings remains to be seen. Further research should dive into possible future adjustments in the regime which could drive or hinder the transition.

Bibliography

- Agency for Science, Technology and Research. (n.d.-a). Collaborations. Retrieved from https://www.a-star.edu.sg/Research/research-focus/food-nutrition-consumer-care/collaborations.
- Agency for Science, Technology and Research. (n.d.-b). SG Food Story IAF Grant Call For Future Foods: Alternative Proteins. Retrieved from https://www.a-star.edu.sg/Research/funding-opportunities/singapore-food-story-r-d-programme-future-food-alternative-protein-iaf-pp-grant-call.
- Agency for Science, Technology and Research. (n.d.-c). A*STAR Launches New Research Institute to Support Singapore's Food Innovation Ecosystem. Retrieved from https://www.a-star.edu.sg/News-and-Events/a-star-news/news/publicity-highlights/a-star-launches-new-research-institute-to-support-singapore%27s-food-innovation-ecosystem.
- Agency for Science, Technology and Research. (n.d.-d). Funding Opportunities. Retrieved from https://www.a-star.edu.sg/Research/funding-opportunities.
- Agri-Food and Veterinary Authority of Singapore. (2013). AVA's Food Security Roadmap for Singapore. Retrieved from https://www.sfa.gov.sg/food-for-thought/article/detail/ava's-food-security-roadmap-for-singapore.
- Animal and Birds Act (2019). Retrieved from https://sso.agc.gov.sg/Act/ABA1965#P1IV-
- Archer Daniel Midlands. (2021). ADM Advances Protein Innovation with Opening of New Plant-based Lab in Singapore. Retrieved from https://www.adm.com/news/news-releases/adm-advances-protein-innovation-with-opening-of-new-plant-based-lab-in-singapore.
- Attwood, S., & Hajat, C. (2020). How will the COVID-19 pandemic shape the future of meat consumption? Public Health Nutrition, 23(17), 3116-3120. doi:10.1017/S136898002000316X
- Audet, R., Lefèvre, S., Brisebois, É., & El-Jed, M. (2017). Structuring tensions and key relations of Montreal seasonal food Markets in the Sustainability Transition of the Agri-food sector. Sustainability, 9(3), 320. https://doi.org/10.3390/su9030320.
- Bajželj, B., Richards, K. S., Allwood, J. M., Smith, P., Dennis, J. S., Curmi, E., Gilligan, C. A. (2014). Importance of food-demand management for climate mitigation. Nature Climate Change, 4, 924–929. doi:10.1038/nclimate2353
- Bashi, Z.; McCullough, R.; Ong, L.; Ramirez, M. (2019). Alternative proteins: The Race for Market Share Is on. Available online: https: //www.mckinsey.com/industries/agriculture/our-insights/alternative-proteins-the-race-for-market-share-is-on. Accessed on 28 September 2021.
- Beers, P. J., Hermans, F., Veldkamp, T., & Hinssen, J. (2014). Social learning inside and outside transition projects: Playing free jazz for a heavy metal audience. NJAS - Wageningen Journal of Life Sciences, 69, 5–13. https://doi.org/10.1016/j.njas.2013.10.001.
- Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. Research Policy, 37(3), 407-429. doi:10.1016/j.respol.2007.12.003

- Bergek, A., Hekkert, M., Jacobsson, S., Markard, J., Sandén, B., Truffer, B. (2015). Technological innovation systems in contexts: conceptualising contextual structures and interaction dynamics. Environ. Innov. Soc. Transit. 16, 51–64.
- Berkhout, F., Smith, A., Stirling, A. (2004). Socio-technological regimes and transition contexts. In: Elzen, B., Geels, F.W., Green, K. (Eds.), System Innovation and the Transition to Sustainability: Theory, Evidence and Policy. Edward Elgar, Cheltenham, pp. 48–75Darnhofer I, Sutherland L, Pinto-Correia T (2015) Conceptual insights derived from case studies on 'emerging transitions' in farming. CABI, Wallingford
- Bord, R., O'Connor, R., & Fisher, R. (2000). In what sense does the public need to understand global climate change? Public Understanding of Science, 9, 205–218.
- Bouvard, V., Loomis, D., Guyton, K. Z., Grosse, Y., Ghissassi, F. E., Benbrahim-Tallaa, L., Straif, K. (2015). Carcinogenicity of consumption of red and processed meat. The Lancet Oncology, 16(16), 1599–1600. http://dx.doi.org/10.1016/ S1470-2045(15)00444-1
- Bui, S., Cardona, A., Lamine, C., & Cerf, M. (2016). Sustainability transitions: Insights on processes of niche-regime interaction and regime reconfiguration in Agri-food systems. Journal of Rural Studies, 48, 92–103. https://doi.org/10.1016/j.jrurstud.2016.10.003.
- Campbell, M.C. (2004). Building a common table: the role for planning in community food systems. J. Plan. Educ. Res. 23 (4), 341–355. https://doi.org/10.1177/ 0739456x04264916.
- Carlsson, B., & Stankiewicz, R. (1991). On the nature, function and composition of technological systems. Evol. Econ. 1 (2), 93–118.
- Centre for Liveable Cities. (2018). Urban System Studies – Food and the City: Overcoming Challenges for Food Security. Retrieved from https://www.clc.gov.sg/docs/default-source/urban-systems-studies/food-and-the-city-overcoming-challenges-for-food-security.pdf
- Chen, P., & Antonelli, M. (2020). Conceptual models of food choice: Influential factors related to foods, individual differences, and society. MDPI AG. doi:10.3390/foods9121898
- Cifuentes, L.M., Freyer, B., Sonnino, R., Fiala, V. (2021). Embedding sustainable diets into urban food strategies: A multi-actor approach. Geoforum, 122, 11-21. doi:10.1016/j.geoforum.2021.03.006
- Cleveland, D. A. (2020). The solution on our plates: Why sustainable plant-based diets are needed to reverse the food-climate-health-equity crisis. In Kevany, K.M. Editor (Ed), Plant-based Diets for Succulence and Sustainability (pp. 31-48). Taylor and Francis.
- Coker, R., Rushton, J., Mounier-Jack, S., Karimuribo, E., Lutumba, P., Kambarage, D., Pfeiffer, D.U., Stärk, K., Rweyemamu, M. (2011) Towards a conceptual framework to support one-health research for policy on emerging zoonoses. Lancet Infect Dis 11:P326–P331
- Crippa, M., Solazzo, E., Guizzardi, D. et al. (2021). Food systems are responsible for a third of global anthropogenic GHG emissions. Nat Food 2, 198–209 (2021). https://doi.org/10.1038/s43016-021-00225-9
- Darnhofer, I., Sutherland, L., Pinto-Correia, T. (2015) Conceptual insights derived from case studies on 'emerging transitions' in farming. CABI, Wallingford

- Detenber, B. H. (2021). Nudging in Singapore: Current Implementation in Three Key Areas. Journal of Asian Economic Integration, 3(1), 74–92. https://doi.org/10.1177/2631684620982776
- Economic Development Board. (2021). Leading cultivated fish company Avant announces new R&D and pilot manufacturing facilities plan in Singapore. Retrieved from https://www.edb.gov.sg/en/about-edb/media-releases-publications/leading-cultivated-fish-company-avant-announces-new-rnd-and-pilot-manufacturing-facilities-plan-in-Singapore.html.
- Edquist, C. (2004). Systems of innovation: perspectives and challenges. In: Fagerberg, J., Mowery, D.C., Nelson, R.R. (Eds.), The Oxford. Handbook of Innovation. Oxford University Press, Oxford.
- El Bilali, H., & Probst, L. (2017). Towards an integrated analytical framework to map sustainability transitions in food systems. Agrofor, 2(2) doi:10.7251/AGRENG1702015T
- El Bilali, H. (2018). Transition heuristic frameworks in research on agro-food sustainability transitions. Environment, Development and Sustainability, 22(3), 1693-1728. doi:10.1007/s10668-018-0290-0
- El Bilali, H. (2019a). Research on agro-food sustainability transitions: Where are food security and nutrition? Food Security, 11(3), 559-577. doi:10.1007/s12571-019-00922-1
- El Bilali, H. (2019b). The Multi-Level Perspective in Research on Sustainability Transitions in Agriculture and Food Systems: A Systematic Review, 9, 74; doi:10.3390/agriculture9040074
- Elzen, B., van Mierlo, B., Leeuwis, C. (2012). Anchoring of innovations: assessing Dutch efforts to harvest energy from glasshouses. Environ. Innov. Soc. Transit. 5, 1e18. http://dx.doi.org/10.1016/j.eist.2012.10.006.
- Enterprise Singapore. (n.d.). FoodInnovate. Retrieved from https://www.enterprisesg.gov.sg/industries/type/food-manufacturing/foodinnovate.
- Enterprise Singapore. (2020a). Alternative protein a boon for food security. What can Spore do to this end? Retrieved from https://www.enterprisesg.gov.sg/media-centre/news/2020/august/alternative-protein-a-boon-for-food-security-what-can-spore-do-to-this-end.
- Enterprise Singapore. (2020b). Enterprise Singapore sets aside over S$55 million to help local agriculture and aquaculture companies build new capabilities and innovate to accelerate growth. Retrieved from https://www.enterprisesg.gov.sg/-/media/esg/files/media-centre/media-releases/2020/jun-2020/enterprise-singapore-sets-aside-over-55-million-to-help-local-agriculture-and-aquaculture-companies-build-new-capabilities-and-innovate-to-accelerate-growth.pdf.
- Enterprise Singapore & Foodvalley NL. (2020). Protein Shift Innovation Scan. A landscape study of food innovators and ecosystem partners driving the protein shift in Singapore and the Netherlands. Retrieved from https://bigideaventures.com/wp-content/uploads/2020/10/ESG_Foodvalley_NL_Protein_Shift_Innovation_Scan.pdf.
- Espinosa, R., Tago, D., Treich, N. (2020). Infectious diseases and meat production. Environmental & Resource Economics, 76(4), 1019-1044. doi:10.1007/s10640-020-00484-3

- European Commission. (2020). Food 2030 pathways for action: Alternative proteins and dietary shift. Retrieved from the Publications Office of the European Union website: https://op.europa.eu/en/publication-detail/-/publication/2a3f49eb-2564-11eb-9d7e-01aa75ed71a1/language-en
- Feyereisen, M., Stassart, P. M., Mélard, F. (2017). Fair trade milk initiative in Belgium: Bricolage as an empowering strategy for change. Sociologia Ruralis, 57(3), 297-315. doi:10.1111/soru.12174
- Firmenich. (2021). Firmenich Opens Culinary & SmartProteins® Innovation Hub in Singapore. Retrieved from https://www.firmenich.com/taste-and-beyond/press-release/firmenich-opens-culinary-smartproteinsr-innovation-hub-singapore.
- Food and Agricultural Organisation of the United Nations. (2017). World's future food security "in jeopardy" due to multiple challenges, report warns. Retrieved from http://www.fao.org/news/story/en/item/471169/icode/
- Food and Agricultural Organisation of the United Nations. (2019). Sustainable Healthy Diets Guiding Principles. Retrieved from FAO website: http://www.fao.org/3/ca6640en/ca6640en.pdf
- Frantzeskaki, N., Loorbach, D., Meadowcroft, J. (2012) Governing societal transitions to sustainability. Int J Sustain Dev 15(1):19–36
- Frantzeskaki, N., V. C. Broto, L. Coenen, and D. Loorbach. (2017). Urban Sustainability Transitions. New York: Routledge.
- Frantzeskaki, N., Hölscher, K., Bach, M., Avelino, F. (2018). Co-creating sustainable urban futures A primer on applying transition management in cities (Future City 11 ed.) Springer.
- Friel, S., Dangour, A., Garnett, T., Lock, K., Chalabi, Z., Roberts, I. (2009). Public health benefits of strategies to reduce greenhouse-gas emissions: food and agriculture. Lancet, 374, 2016–2025.
- Gaitán-Cremaschi, D., Klerkx, L., Duncan, J., Trienekens, J. H., Huenchuleo, C., Dogliotti, S., Rossing, W. A. H. (2019). Characterising diversity of food systems in view of sustainability transitions. A review. Agronomy for Sustainable Development, 39(1), 1-22. doi:10.1007/s13593-018-0550-2
- Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. Research Policy, 31(8–9), 1257–1274. https://doi.org/10.1016/s0048 -7333(02)00062-8.
- Geels F.W. (2004). From sectoral systems of innovation to socio-technical systems. Insights about dynamics and change from sociology and institutional theory. Research Policy 33, 897–920.
- Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. Research Policy, 36(3), 399-417. doi:10.1016/j.respol.2007.01.003
- Geels, F. W. (2010). Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. Research Policy, 39(4), 495–510. https://doi.org/10.1016/j.respol.2010.01.022.
- Geels, F. W. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. Environmental Innovation and Societal Transitions, 1(1), 24–40. https://doi.org/10.1016/j.eist.2011.02.002.

- Geels, F.W. (2014). Reconceptualising the co-evolution of firms-in-industries and their environments: developing an inter-disciplinary triple embeddedness framework. Res. Policy 43 (2), 261–277.
- Geels, F.W. (2018) Socio-Technical Transitions to Sustainability. Retrieved from http://environmentalscience.oxfordre.com/view/10.1093/acrefore/9780199389414.001.0001/acrefore-9780199389414-e-587.
- Genus, A., & Coles, A.M. (2008). Rethinking the multi-level perspective of technological transitions. Research Policy 37, 1436–1445.
- Gernert, M., El Bilali, H., & Strassner, C. (2018). Grassroots initiatives as sustainability transition pioneers: Implications and lessons for urban food systems. Urban Science, 2(1), 23. doi:10.3390/urbansci2010023
- Grasso, S., & Jaworska, S. (2020). Part meat and part plant: Are hybrid meat products fad or future? Foods, 9(12) doi:10.3390/foods9121888
- Hargreaves, T., Haxeltine, A., Longhurst, N., Seyfang, G. (2011). Sustainability transitions from the bottom-up: Civil society, the multi-level perspective and practice theory. Working Paper—Centre for Social and Economic Research on the Global Environment, https://www.econstor.eu/obitstream/10419/48796/1/662352246.pdf.
- Hargreaves, T., Longhurst, N., Seyfang, G. (2013). Up, down, round and round: Connecting regimes and practices in innovation for sustainability. Environment and Planning A, 45(2), 402–420. https ://doi.org/10.1068/a45124.
- Harwatt, H., Sabaté, J., Eshel, G., Soret, S., Ripple, W. (2017). Substituting beans for beef as a contribution toward US climate change targets. Climate Change, 143, 261–270. http://doi.org/10.1007/s10584-017-1969-1
- Hekkert, M.P., Suurs, R.A.A., Negro, S.O., Kuhlmann, S., Smits, R.E.H.M. (2007). Functions of innovation systems: a new approach for analysing technological change. Technol. Forecast. Soc. Change 74 (2007), 413–432.
- Hinrichs, C. (2014). Transitions to sustainability: A change in thinking about food systems change? Agriculture and Human Values, 31(1), 143-155. doi:10.1007/s10460-014-9479-5
- Ignaszewski, E. (2021). Top eight alternative protein trends to watch in 2021. *Good Food Institute.* Retrieved from https://gfi.org/blog/2021-alternative-protein-trends/.
- Ingram, J. (2015) Framing niche-regime linkage as adaptation: an analysis of learning and innovation networks for sustainable agriculture across Europe. J Rural Stud 40:59–75. https://doi.org/10.1016/j. jrurstud.2015.06.003
- IntegriCulture (2020). IntegriCulture Inc. and Shiok Meats Pte. Ltd. collaborate to scale cell-based shrimp meat. Retrieved from https://integriculture.jp/news/398/?locale=en
- Intergovernmental Panel on Climate Change. (2020). Climate Change and Land. An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. Retrieved from IPCC website: https://www.ipcc.ch/site/assets/uploads/sites/4/2020/02/SPM_Updated-Jan20.pdf
- Jacobsson, S., & Bergek, A. (2011). Innovation system analyses and sustainability transitions: Contribu- tions and suggestions for research. Environmental Innovation and Societal Transitions. https://doi. org/10.1016/j.eist.2011.04.006.

- Järnberg, L., Enfors Kautsky, E., Dagerskog, L., Olsson, P. (2018). Green niche actors navigating an opaque opportunity context: Prospects for a sustainable transformation of Ethiopian agriculture. Land use Policy, 71, 409-421. doi:10.1016/j.landusepol.2017.11.053
- Jorgensen, U. (2012). Mapping and navigating transitions – the multi-level perspective compared with arenas of development. Res. Policy 41, 996–1010.
- Kemp, R., & Rotmans, J. (2004). Managing the transition to sustainable mobility. System innovation and the transition to sustainability. In: Elzen, B., Geels, F.W., Green, K. (Eds.), Theory, Evidence and Policy. Edward Elgar, Cheltenham.
- Kemp, R., & Loorbach, D. (2005). Dutch policies to manage the transition to sustainable energy. In: Beckenbach, F., Hampicke, U., Leipert, C., et al. (Eds.), Jahrbuch Okologische Okonomik: Innovationen und Transformation, vol. 4. Metropolis Verlag, Marburg, pp. 123–150.
- Kemp, R., Loorbach, D., & Rotmans, J. (2007). Transition management as a model for managing processes of co-evolution towards sustainable development. International Journal of Sustainable Development & World Ecology, 14, 78–91.
- Kern, F., & Smith, A. (2008). Restructuring energy systems for sustainability? energy transition policy in the Netherlands Elsevier BV. doi:10.1016/j.enpol.2008.06.018
- Klein Woolthuis, R., Lankhuizen, M., Gilsing, V. (2005). A system failure framework for innovation policy design. Technovation 25, 609–619.
- Kivimaa P, Kern F (2016) Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. Res Policy 45: 205–217. https://doi.org/10.1016/j.respol.2015.09.008
- Kuokkanen, A., Nurmi, A., Mikkilä, M., Kuisma, M., Kahiluoto, H., Linnanen, L. (2018). Agency in regime destabilisation through the selection environment: The Finnish food system's sustainability transition. Research Policy, 47(8), 1513-1522. doi:10.1016/j.respol.2018.05.006
- Lachman, D. A. (2013). A survey and review of approaches to study transitions. Energy Policy, 58, 269–276. https://doi.org/10.1016/j.enpol.2013.03.013.
- Lamine, C. (2011). Transition pathways towards a robust ecologisation of agriculture and the need for system redesign. cases from organic farming and IPM. Journal of Rural Studies, 27(2), 209-219. doi:10.1016/j.jrurstud.2011.02.001
- Lamine, C., Renting, H., Rossi, A., Wiskerke, J.S.C., Brunori, G. (2012) Agri- food systems and territorial development: innovations, new dynamics and changing governance mechanisms. In: Farming systems re- search into the 21st century: the new dynamic. Springer Netherlands, Dordrecht, pp. 229–256. https://doi.org/10.1007/978- 94-007-4503-2_11
- Lim, K. T. (2021). Singapore: food security despite the odds. Retrieved from Singapore Food Agency: https://www.sfa.gov.sg/food-for-thought/article/detail/singapore-food-security-despite-the-odds.
- Liu, W., Oosterveer, P., Spaargaren, G. (2016). Promoting sustainable consumption in China: A conceptual framework and research review. Journal of Cleaner Production, 134, 13–21. https://doi. org/10.1016/j.jclepro.2015.10.124.

- Loorbach, D. (2007). Transition management: New mode of governance for sustainable development. Utrecht: International Books.
- Loorbach, D. (2010). Transition management for sustainable development: A prescriptive, complexity-based governance framework. ove_1471 161.184
- Lynch, J., & Pierrehumbert, R. (2019). Climate impacts of cultured meat and beef cattle. Frontiers in Sustainable Food Systems, 3 doi:10.3389/fsufs.2019.00005
- Markard, J., & Truffer, B. (2008). Technological innovation systems and the multi-level perspective: Towards an integrated framework. Research Policy, 37(4), 596-615. doi:10.1016/j.respol.2008.01.004
- Markard, J., Raven, R., & Truffer, B. (2012). Sustainability transitions: An emerging field of research and its prospects. Research Policy, 41(6), 955-967. doi:10.1016/j.respol.2012.02.013
- Marsden, T. (2013). From post-productionism to reflexive governance: Contested transitions in securing more sustainable food futures. Journal of Rural Studies 29: 123–134.
- Meadowcroft, J. (2012). Engaging with the politics of sustainability transitions. Environmental Innovation and Societal Transitions, 1, 70–75Meynard J-M, Jeuffroy M-H, Le Bail M, Lefèvre A, Magrini M-B, Michon C (2017) Designing coupled innovations for the sustainability transition of agrifood systems. Agric Syst 157:330–339. https:// doi.org/10.1016/j.agsy.2016.08.002
- Meynard, J. M., Jeuffroy, M. H., Le Bail, M., Lefèvre, A., Magrini, M.B., Michon, C. (2017). Designing coupled innovations for the sustainability transition of agrifood systems. Agricultural Systems, 157, 330–339. https://doi.org/10.1016/j.agsy.2016.08.002.
- Micha, R., Shulkin, M. L., Peñalvo, J. L., Khatibzadeh, S., Singh, G. M., Rao, M., Mozaffarian, D. (2017). Etiologic effects and optimal intakes of foods and nutrients for risk of cardiovascular diseases and diabetes: Systematic reviews and meta-analyses from the nutrition and chronic diseases expert group (NutriCoDE). PLoS One, 12(4), e0175149. doi:10.1371/journal.pone.0175149
- Ministry of Health. (n.d.). What is My Healthy Plate? Retrieved from https://www.healthhub.sg/programmes/55/my-healthy-plate.
- Ministry of Sustainability and Environment. (2020). Singapore Food Story Campaign and Launch of the First Grant Call for SG Eco Fund. Retrieved from https://www.mse.gov.sg/resource-room/category/2020-11-25-press-release-on-singapore-food-story-campaign-and-launch-of-the-first-grant-call-for-sg-eco-fund/
- Ministry of Sustainability and Environment. (2021). Speech at Launch Of The Future Ready Food Safety Hub at NTU - Ms Grace Fu. Retrieved from https://www.mse.gov.sg/resource-room/category/2021-04-27-speech-at-future-ready-food-safety-hub.
- Ministry of Trade and Industry. (2019). Agri-Food Innovation Park (AFIP) Factsheet. Retrieved from https://www.mti.gov.sg/-/media/MTI/COS-2019/Factsheet_AFIP.pdf.
- Ministry of Trade and Industry. (2021). Speech by MOS Alvin Tan at the Opening of Buhler-Givaudan APAC Protein Innovation Center. Retrieved from

https://www.mti.gov.sg/Newsroom/Speeches/2021/04/Speech-by-MOS-Tan-at-the-Opening-of-Buhler-Givaudan-APAC-Protein-Innovation-Center.

- Moore, J. (2015). ecological footprints and lifestyle archetypes: Exploring dimensions of consumption and the transformation needed to achieve urban sustainability. Sustainability, 7(4), 4747–4763. https://doi.org/10.3390/su7044747.
- Negro, S.O. & Hekkert, M.P. (2008). Explaining the success of emerging technologies by innovation system functioning: the case of biomass digestion in Germany. Technol. Anal. Strateg. Manag. 20 (4), 465–482.
- Ng, H. (2018). Decentralised Institutions and Electoral Authoritarianism: The Case of Town Councils in Singapore. Asian studies review, vol. 42, no. 3, pp. 459-478.
- Novacek, M. (2008). Engaging the public in biodiversity issues. Proceedings of the National Academy of Sciences of the United States of America, 105, 11571–11578.
- Organisation for Economic Co-operation and Development & Food Agriculture Organisation. (2021). OECD-FAO AGRICULTURAL OUTLOOK 2021-2030. Retrieved from https://www.fao.org/3/CB5332EN/Meat.pdf.
- Ornish, D., Magbanua, M. J. M., Weidner, G., Weinberg, V., Kemp, C., Green, C., Haqq, C. M. (2008). Changes in prostate gene expression in men undergoing an intensive nutrition and lifestyle intervention. Proceedings of the National Academy of Sciences, 105(24), 8369–8374.
- Plumecocq, G., Debril, T., Duru, M., Magrini, M.B., Sarthou, J.P., Therond, O. (2018) The plurality of values in sustainable agriculture models: diverse lock-in and coevolution patterns. Ecol Soc 23(1):21. https://doi.org/10.5751/ES-09881-230121
- Quek, E. (2021). Worth Watching in 2021: Plant-based boom sets stage for Singapore to become alternative meats hub. *The Straits Times.* Retrieved from https://www.straitstimes.com/life/food/worth-watching-in-2021-plant-based-boom-sets-stage-for-spore-to-become-alternative-meats
- Raman, S., & Mohr, A. (2014). Biofuels and the role of space in sustainable innovation journeys. Journal of Cleaner Production, 65, 224–233. https://doi.org/10.1016/j.jclepro.2013.07.057.
- Reckwitz, A. (2002). Toward a theory of social practices: a development in culturalist theorising. European Journal of Social Theory 52 243–263
- Rip, A., & Kemp, R. (1998). Technological change. In S. Rayner & E. L. Malone (Eds.), Human choice and climate change (Vol. 2, pp. 327–399). Columbus, OH: Battelle Press.
- Rotmans, J., Kemp, R., & van Asselt, M. (2001). More evolution than revolution: Transition management in public policy. Foresight, 3(1), 15–31. https://doi.org/10.1108/14636680110803003.
- Rotmans, J., & Loorbach, D. (2009). Complexity and transition management. Journal of Industrial Ecology, 13(2), 184–196. https://doi.org/10.1111/j.1530-9290.2009.00116.x.
- SATS Ltd. (2019). SATS develops market for sustainable food products in Asia. Retrieved from https://www.sats.com.sg/docs/default-source/media-releases/2019/21nov19-sats-develops-market-for-sustainable-food-products-in-asia.pdf?sfvrsn=6616ff6d_2.

- Schot, J., & Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys: Theory, findings, research agenda, and policy. Technology Analysis & Strategic Management, 20(5), 537–554. https://doi.org/10.1080/09537320802292651.
- Schwingshackl, L., Hoffmann, G., Lampousi, A.-M., Knüppel, S., Iqbal, K., Schwedhelm, C., Boeing, H. (2017). Food groups and risk of type 2 diabetes mellitus: A systematic review and meta-analysis of prospective studies. European Journal of Epidemiology, 32(5), 363–375. doi:10.1007/s10654-017-0246-y
- Sexton, A. E., Garnett, T., & Lorimer, J. (2019). Framing the future of food: The contested promises of alternative proteins. Environment and Planning. E, Nature and Space (Print), 2(1), 47-72. doi:10.1177/2514848619827009
- Seyfang, G. & Smith, A. (2007) "Grassroots innovations for sustainable development: towards a new research and policy agenda" Environmental Politics 16 584–603
- Shove E. & Pantzar, M. (2005), "Consumers, producers and practices: understanding the invention and reinvention of Nordic walking" Journal of Consumer Culture 51 43–64
- Shove, E. & Walker, G. (2007) CAUTION! Transitions ahead: politics, practice, and sustainable transition management. Environ Plan A 39(4):763–770
- Singapore Food Agency. (n.d.-a) Singapore's Food Supply. Retrieved from Singapore Food Agency. Retrieved from https://www.sfa.gov.sg/food-farming/singapore-food-supply/the-food-we-eat#:~:text=Singapore's%20Food%20Supply,-The%20Food%20We&text=With%20little%20farming%20land%2C%20Singapore,13%25%20of%20all%20the%20vegetables.
- Singapore Food Agency. (n.d.-b). Safety of Alternative Protein. Retrieved from https://www.sfa.gov.sg/food-information/risk-at-a-glance/safety-of-alternative-protein.
- Singapore Food Agency. (n.d.-c). Food Safety Education: Antimicrobial resistance. Retrieved from https://www.sfa.gov.sg/food-information/food-safety-education/antimicrobial-resistance.
- Singapore Food Agency. (n.d.-d). Singapore Food Story R&D Programme. Retrieved from https://www.sfa.gov.sg/food-farming/singapore-food-story.
- Singapore Food Agency. (2020). SFA awards close to S$40 million under 30x30 Express Grant to accelerate ramp up in local food production. Retrieved from https://www.sfa.gov.sg/docs/default-source/default-document-library/sfa-media-release---award-of-30x30-express-grant-call.pdf.
- Singapore Institute of Technology. (2021). SIT Bolsters Food Technology Offerings to Support Burgeoning Agri-Food Sector in Singapore. Retrieved from https://www.singaporetech.edu.sg/digitalnewsroom/sit-bolsters-food-technology-offerings-to-support-burgeoning-agri-food-sector-in-singapore/.
- SGProtein. (2021). About us. Retrieved from https://www.eatsgprotein.com/.
- Smith, A., Stirling, A., & Berkhout, F. (2005). The governance of sustainable socio-technical transitions. Research Policy, 34(10), 1491–1510. https://doi.org/10.1016/j.respol.2005.07.005.
- Smith, A. (2007). Translating sustainabilities between green niches and socio-technical regimes. Technology Analysis & Strategic Management, 19(4), 427-450. doi:10.1080/09537320701403334

- Smith, A., Voß, J.-P., Grin, J. (2010). Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges. Research Policy, 39(4), 435–448. https://doi. org/10.1016/j.respol.2010.01.023.
- Smith, A. & Raven, R. (2012) What is protective space? Reconsidering niches in transitions to sustainability. Res Policy 41(6):1025–1036. https:// doi.org/10.1016/j.respol.2011.12.012
- Specht, E. A., Welch, D. R., Rees Clayton, E. M., Lagally, C. D. (2018). Opportunities for applying biomedical production and manufacturing methods to the development of the clean meat industry. Biochemical Engineering Journal, 132, 161-168. doi:10.1016/j.bej.2018.01.015
- Startup SG (n.d.-a). General Information: Innovate 360. Retrieved from https://www.startupsg.gov.sg/profiles/5944.
- Startup SG (n.d.-b). General Information: SingCell. Retrieved from https://www.startupsg.gov.sg/profiles/20933.
- Statista. (2020). Share of Singaporean respondents with the following dietary preferences as of February 2020. Retrieved from https://www.statista.com/statistics/1102014/singapore-dietary-preferences/.
- Stephens, N., Di Silvio, L., Dunsford, I., Ellis, M., Glencross, A., Sexton, A. (2018). Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture. Trends in Food Science & Technology, 78, 155-166. doi:10.1016/j.tifs.2018.04.010
- Sustainability Transitions Research Network. (2010). A mission statement and research agenda for the Sustainability Transitions Research Network. Retrieved from http://www.transitionsnetwork.org/files/STRN_research_agenda_20_August_2 010(2).pdf.
- Suurs, R.A. & Hekkert, M.P. (2009). Cumulative causation in the formation of a technological innovation system: the case of biofuels in the Netherlands. Technol.Forecast. Soc. Change 76 (8).
- Tan, A. (2021). World's first commercial cultured meat production facility operational in Singapore. *The Straits Times.* Retrieved from https://www.straitstimes.com/singapore/environment/worlds-first-commercial-cultured-meat-production-facility-operational-in.
- Teh, C. (2019). $68m fund to turn labs into food factories of the future. *The Straits Times.* Retrieved from https://www.straitstimes.com/singapore/68m-fund-to-turn-labs-into-food-factories-of-the-future.
- Terazono, E., & Meyer, G. (2020). Pandemic accelerates shift to meat substitutes. *The Financial Times*. Retrieved from https://www.ft.com/content/0127984a-6def-4040-9bca-002b6ffd4e0a.
- Thomas, O.Z., & Bryant, C. (2021). Don't have a cow, man: Consumer acceptance of animal-free dairy products in five countries. *Frontiers in Sustainable Food Systems, 5* doi:10.3389/fsufs.2021.678491

- Tziva, M., Negro, S. O., Kalfagianni, A., Hekkert, M. P. (2020). Understanding the protein transition: The rise of plant-based meat substitutes. Environmental Innovation and Societal Transitions, 35, 217-231. doi:10.1016/j.eist.2019.09.004
- United Nation Development Programme. 2020. How cities can fight food loss and waste. Retrieved from: https://www.undp.org/content/undp/en/home/blog/2020/how-cities-can-fight-food-loss-and-waste-.html#:~:text=Cities%20will%20be%20home%20to,the%20world's%20food%20by%202050.
- United Nations Framework Convention on Climate Change. (2015). Adoption of the Paris agreement (Report No. FCCC/CP/2015/L.9/ Rev.1). Retrieved from http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf
- Unruh, G. (2000). Understanding carbon lock in. Energy Policy 28 817–830
- van de Poel, I. (2000). On the role of outsiders in technical development. Technology Analysis & Strategic Management 12 (3), 383– 397.
- van de Poel, I. (2003). The transformation of technological regimes. Research Policy 32, 49–68.
- van Thiel, S. (2014). Research Methods in Public Administration and Public Management: An Introduction. Nijmegen: Routledge.
- Vinnari, M., & Vinnari, E. (2014). A framework for sustainability transition: The case of plant-based diets. Journal of Agricultural and Environmental Ethics, 27(3), 369-396. doi:10.1007/s10806-013-9468-5
- Voß, J.P., Smith, A., Grin, J. (2009). Designing long-term policy: Rethinking transition management. Policy Sciences, 42, 275–302.
- Walker, G., & Shove, E. (2007) Ambivalence, sustainability and the governance of socio-technical transitions. J Environ Policy Plan 9(3–4):213–225
- Wals, A. E. J. (2007). Social learning towards a sustainable world: Principles, perspectives, and praxis. Wageningen: Wageningen Academic Publishers.
- Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Murray, C. J. L. (2019). Food in the Anthropocene: The EAT – Lancet Commission on healthy diets from sustainable food systems. The Lancet, 393(10170), 447–492. https://doi.org/10.1016/S0140-6736(18)31788-4
- World Economic Forum. (2019). Meat: the Future series (Alternative Proteins). Geneva: Oxford Martin School, Oxford University for the World.
- Yeoh, K. (2008). Singapore's biomedical sciences landscape. Journal of Commercial Biotechnology, 14(2), 141-148. doi:10.1057/palgrave.jcb.3050083
- Yin, R. K. (2014). Case Study Research: Design and Methods. SAGE Publications.

Appendix 1: Work plan

Table 19: Work plan

Phase/ Action	Timeline
Phase 1: Identify food system and actors - Identify food system and key actors - Prepare interview guides and questions - Prepare survey forms - Send out interview requests - Send out survey forms	June 2021
Phase 2: Identify landscape factors and assess actors' responses - Using secondary data, identify landscape factors and regime actors' responses - Interview key actors identified	June – July 2021
Phase 3: Assess functional dynamics of TIS - Using secondary data, identify niche entrepreneurs' responses to factors and strategies from Phase 2 - Interview key actors identified - Using secondary data and interview responses, assess functional dynamics of TIS	June – August 2021
Phase 4: Assess "images", "skills" and "materials" of consumers with regards to alternative proteins - Survey participants identified - Using secondary data and survey results, assess consumers' perceptions	July – August 2021
Phase 5: Identify key drivers and barriers	August – September 2021
Phase 6: Assess influence of driving and hindering factors on the pathway of the transition	August – September 2021
Data analysis	June – September 2021
Thesis writing	September – October 2021
Submission of thesis proposal	21st June 2021 (GO-NO GO Decision on 25th June 2021)
Submission of thesis draft	5th October 2021
Submission of final thesis	1st November 2021

Appendix 2: Interview guide

A. Interview protocol

The consent provided by the 16 interviewees included the following:

- Interviews kept strictly confidential where all responses are anonymised.
- Understanding of what the interview and research entail
- Permission to record and transcribe the online interview on the basis that the recording and transcript are not shared with anyone else other than the thesis professors grading this thesis. Recording and transcripts are deleted upon the completion of the thesis
- Draft of the thesis shared with the interviewees to give them an opportunity to correct any factual errors

B. Profile of the interviewees obtained

- Name and designation
- Professional background
- Role in the institution
- Background information about the institution

C. Key interview questions

Table 20: Key interview questions

Variables	Indicators	Questions	Actors who were asked the questions
Regime responses	Government funding and support	- What is your opinion of the adequacy of the government funding and overall support for the alt-pro sector?	Entrepreneurs, Non-Profit Organisation, Governmental agencies, Research and Education Institutes, Accelerators
	Regulatory system	- What is your opinion on the regulatory system relating to alternative proteins?	Entrepreneurs, Non-Profit Organisation, Governmental agencies, Research and Education Institutes, Accelerators
	Responses from incumbent companies	- In your opinion, (how) are the incumbent (meat) companies and industry associations reacting towards the alt-pro sector? - If any, what are your plans to partner with the incumbent (meat) companies?	Entrepreneurs, Governmental Agencies
Strength of niches	Breadth of products and technologies	- What is your opinion on the breadth of products and technology developed? - What do you think of its potential for further development?	Entrepreneurs, Non-Profit Organisation, Governmental agencies, Research and Education Institutes, Accelerators
	Availability of monetary and human capital	- What is your opinion on the availability of monetary and human capital?	Entrepreneurs, Non-Profit Organisation, Governmental agencies, Research and Education Institutes, Accelerators
	Assessment of knowledge development	- How well do you think that the knowledge relating to the alternative protein sector has been developed? - What is your opinion of the learning curves relating to alternative proteins?	Entrepreneurs, Non-Profit Organisation, Governmental agencies, Research and Education Institutes, Accelerators
	Assessment of knowledge diffusion	- How well do you think the knowledge relating to the alternative protein sector has been diffused horizontally and vertically?	Entrepreneurs, Non-Profit Organisation, Governmental agencies, Research and Education Institutes, Accelerators

	Bibliometrics	- What is number of citations, volume of publications and orientation/direction of publications with regards to alternative proteins? - Do you assess this to be sufficient?	Entrepreneurs, Research and Education Institutes
Consumers perception	Consumer awareness	- What strategies are being launched currently to raise consumer awareness? - Do you assess this to be sufficient?	Entrepreneurs, Non-Profit Organisation, Governmental agencies, Research and Education Institutes
Main research question: Influence of drivers and barriers on the pathway of transition	Key barriers and uncertainties	- What are the main uncertainties and barriers hindering the transition? - What other resources are lacking to further drive the transition?	Entrepreneurs, Non-Profit Organisation, Governmental agencies, Research and Education Institutes, Accelerators
	Transition pathway and adjustments in regime	- How effective do you think meat and seafood will be substituted by alternative proteins? - How much market share can the alternative protein sector capture from the meat and seafood sector in the next 10 years? - Who do you view as your main competitor? - How much legitimacy has the alternative protein sector achieved amongst its stakeholders?	Entrepreneurs, Governmental agencies, Research and Education Institutes

D. List of Respondents

Table 21: List of respondents

Sn.	Category	Source	Interview Duration (hh:mm:ss)
1	Accelerator (R1)	LinkedIn	1:22:07
2	Accelerator (R2)	LinkedIn	1:32:43
3	Accelerator (R16)	LinkedIn	58:28
4	Education Institute (R3)	LinkedIn	1:31:45
5	Education Institute/ Entrepreneur (R8)	LinkedIn	1:37:27
6	Governmental agency (R4)	LinkedIn	58:01
7	Governmental agency and research institute (R12)	LinkedIn	59:56
8	Governmental agency and research institute (R13)	Snowball	56:48
9	Entrepreneur (R5)	LinkedIn	55:20
10	Entrepreneur (R6)	LinkedIn	1:40:28
11	Entrepreneur (R7)	LinkedIn	1:09:48
12	Entrepreneur (R9)	LinkedIn	34:52
13	Entrepreneur (R10)	LinkedIn	1:36:26
14	Entrepreneur (R11)	LinkedIn	45:42
15	Entrepreneur (R15)	LinkedIn	56:48
16	Non-profit organisation (R14)	Snowball	1:26:28

Appendix 3: Survey guide

A. Survey Protocol

The consent provided by the 170 survey respondents included the following:

- Survey results to be kept strictly confidential where all responses will be anonymised, aggregated and not traceable to any individual respondent.
- Any information collected through this survey will only be used for this thesis and will be deleted after the thesis project ends.

B. Profile of the survey respondents obtained, for which the respondent can choose not to answer any particular question

- Age group
- Gender
- Annual income
- Highest education level
- Dietary preference

C. Survey questions

Table 22: Survey questions

Indicators	Survey Questions
Factors influencing choice of protein	**1. Which factors influence your choice of protein? (More than 1 selection possible)** a. Taste b. Nutrition c. Price d. Environmental impacts e. Accessibility f. Others: _____
Images a. Perceived nutritional value b. Perceived price c. Perceived environmental impacts d. Perceived taste e. Perceived accessibility	**Nutritional Value:** **2. In your opinion, how do you rate the nutritional value of (i) meat and seafood, (ii) whole-foods, plant-based, (iii) processed, plant-based, (iv) cultivated protein, (v) insect protein?** a. Extremely nutritious b. Somewhat nutritious c. Neutral d. Somewhat not nutritious e. Not nutritious at all **Price:** **3. In your opinion, how do you rate the affordability of (i) meat and seafood, (ii) whole-foods, plant-based, (iii) processed, plant-based, (iv) cultivated protein, (v) insect protein?** a. Extremely affordable b. Somewhat affordable c. Neutral d. Somewhat not affordable e. Not affordable at all **Environmental Impacts:** **4. In your opinion, how do you rate the environmental impacts of (i) meat and seafood, (ii) whole-foods, plant-based, (iii) processed, plant-based, (iv) cultivated protein, (v) insect protein?** a. Extremely environmentally friendly b. Somewhat environmentally friendly c. Neutral

	d. Somewhat not environmentally friendly e. Not environmentally friendly at all **Taste:** **5. In your opinion, how do you rate the taste of (i) meat and seafood, (ii) whole-foods, plant-based, (iii) processed, plant-based, (iv) cultivated protein, (v) insect protein?** f. Extremely tasty g. Somewhat tasty h. Neutral i. Somewhat not tasty j. Not tasty at all **Accessibility:** **6. In your opinion, how do you rate the accessibility of (i) meat and seafood, (ii) whole-foods, plant-based, (iii) processed, plant-based, (iv) cultivated protein, (v) insect protein?** a. Extremely accessible b. Somewhat accessible c. Neutral d. Somewhat not accessible e. Not accessible at all
Skills: - Familiarity with using alternative proteins in cooking	**7. When you cook, how often do you use alternative proteins to substitute meat/seafood?** a. All the time b. Most of the time c. Rarely d. Never e. I don't cook 8. **To what extent are you familiar with the alternative proteins you can use to substitute meat/seafood when you cook?** *(Respondents who responded 'I don't cook' to Question 9 will not be shown this question)* a. Extremely familiar b. Somewhat familiar c. Neutral d. Somewhat not familiar e. Not familiar at all
Materials: - Perceived changes in availability of alternative proteins in supermarkets and F&B outlets	**9. How has the range of alternative proteins in the supermarkets changed over the years?** a. Increased b. Stayed the same c. Decreased d. I don't notice it e. Others:_____ **10. How has the range of alternative proteins in the F&B outlets (restaurants, kopitiams, hawker centres etc.) changed over the years?** a. Increased b. Stayed the same c. Decreased d. I don't notice it e. Others:_____
Main obstacles hindering the switch to alternative proteins	**11. What are the main reasons stopping you from substituting meat in your diet with alternative proteins?** a. Health: I think that meat and seafood provide me with nutrients not available in alternative proteins b. Awareness: I am not aware of the environmental impacts of meat and seafood c. Nonchalance: I am aware of the environmental impacts of meat and seafood, but I do not care d. Price: I think that alternative proteins are more expensive than meat and seafood e. Taste: I think that meat and seafood are tastier f. Authenticity in local cuisine: I think that meat and seafood in local cuisine should not be substituted with alternative proteins as it compromises its authenticity g. Accessibility: I think that meat and seafood options are more easily accessible everywhere h. Social pressure: I eat what my family and/or friends eat i. Social image: I think that eating meat and seafood is more of a social norm **j.** Social desirability: I think that eating meat and seafood makes me a cooler person k. Others:_____

D. Demographics of survey respondents

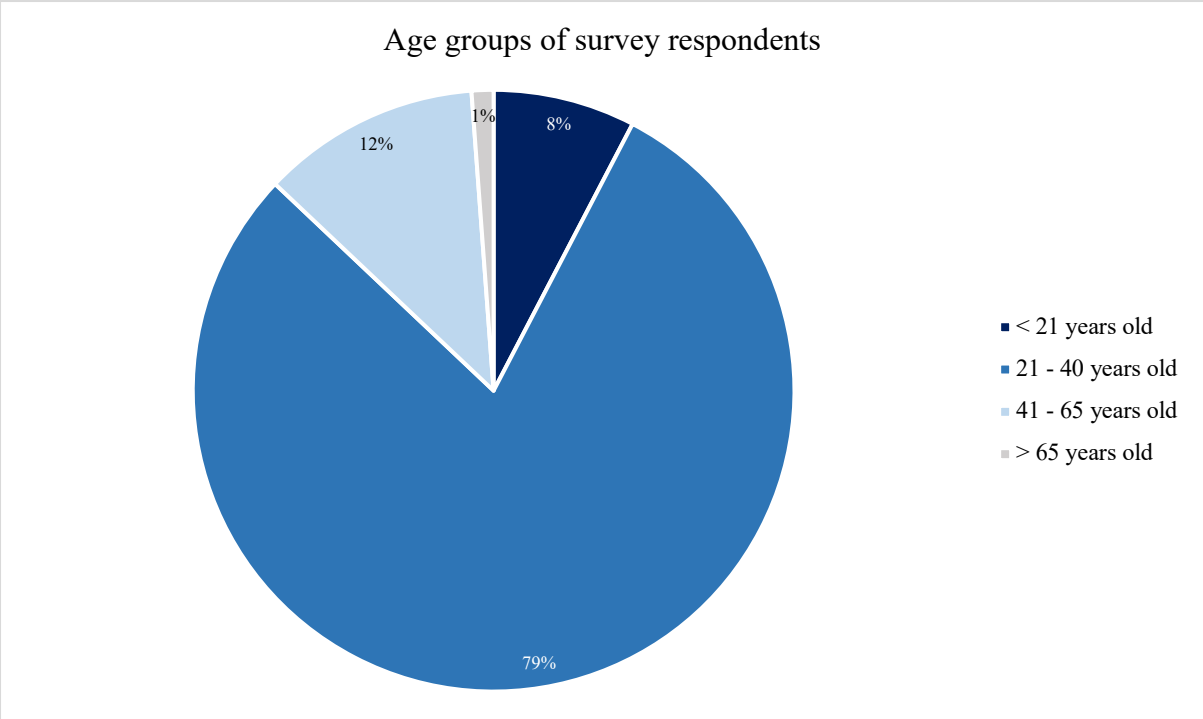


Figure 13: Age groups of survey respondents

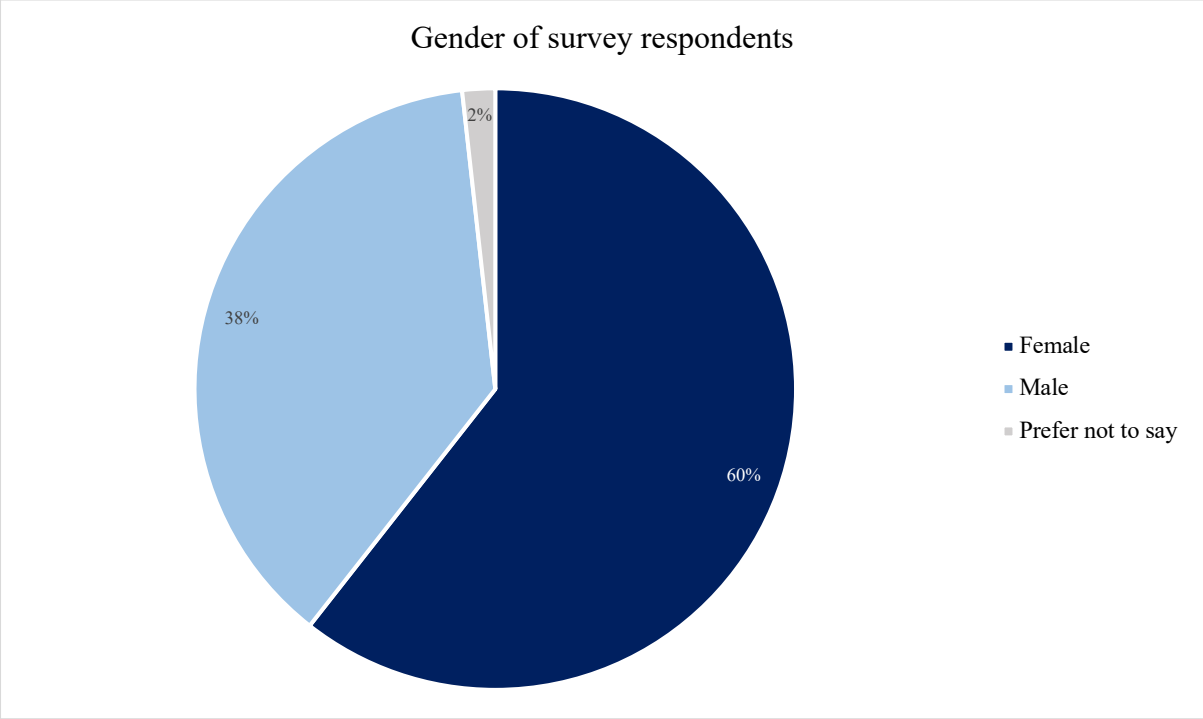


Figure 14: Gender of survey respondents

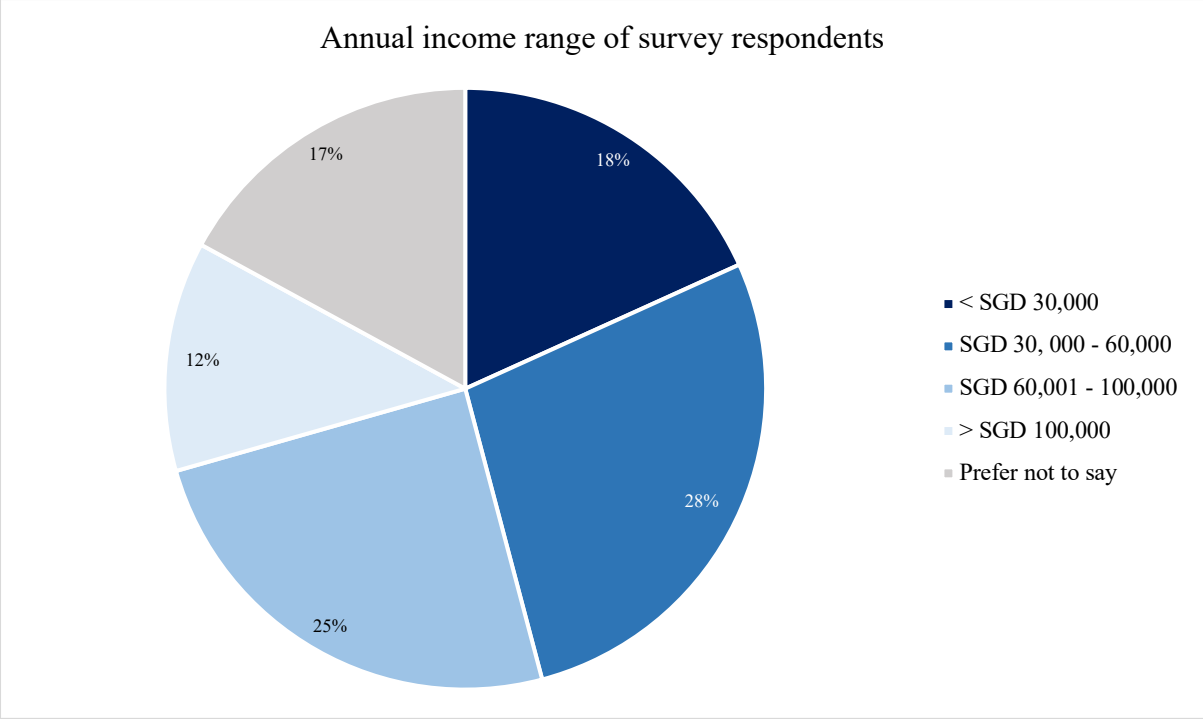


Figure 15: Annual income ranges of survey respondents

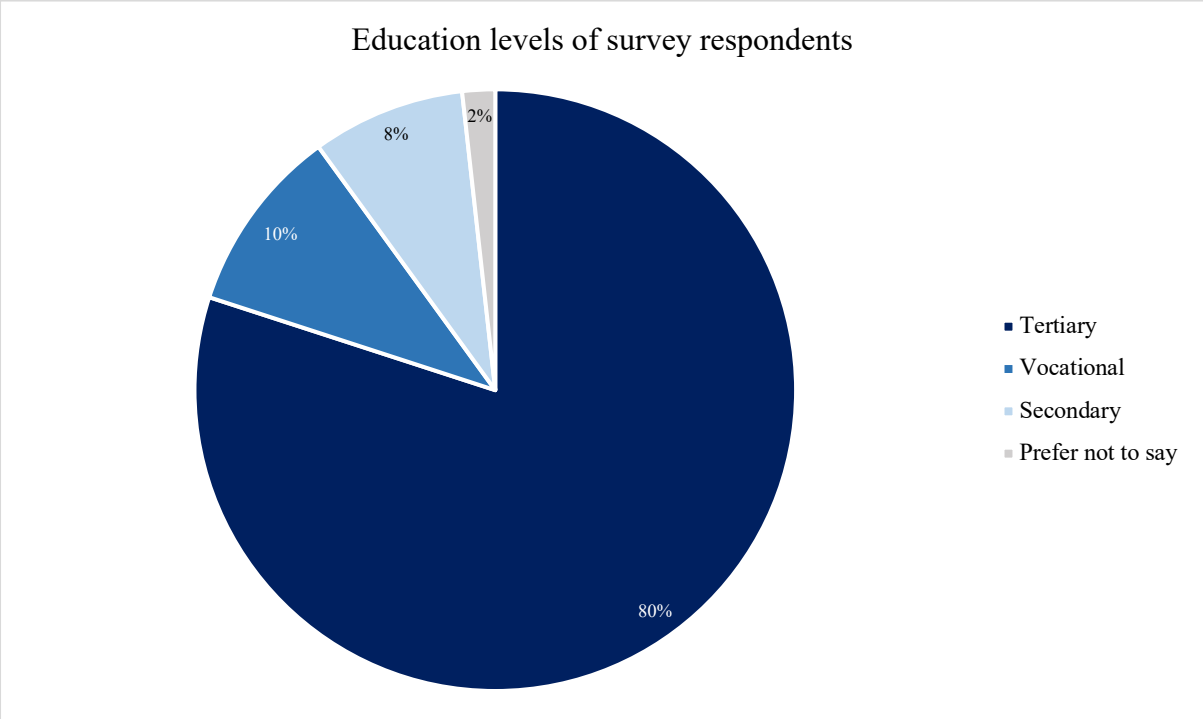


Figure 16: Education levels of survey respondents

Appendix 4: Average perception ratings of all protein types for each criteria

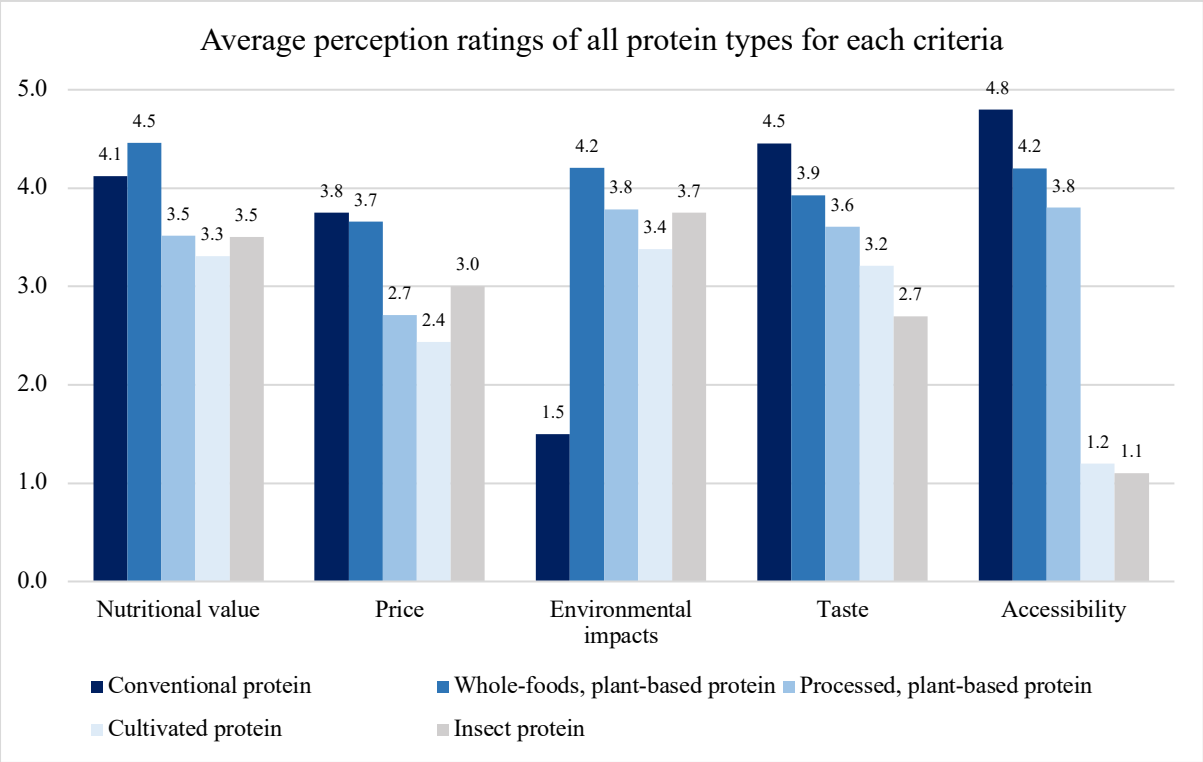


Figure 17: Average perception ratings of all protein types for each criteria

From Figure 17, in terms of taste, meat and seafood were rated as the tastiest (4.5 out of 5), followed by whole-foods, plant-based alternative protein (3.9) and then cultivated protein (3.2). Insect protein was rated the least tasty (2.7). With regards to affordability, cultivated protein was rated the least affordable (2.4), while meat and seafood (3.8) and whole-foods, plant-based protein (3.7) were rated the most affordable. Processed, plant-based protein was rated the second least affordable (2.7), likely due to the current range of processed, plant-based protein products such as Impossible Foods and Beyond Meat, which usually have a higher price tag than its meat counterparts (R6). Ratings of nutritional value followed a similar pattern as price, whereby whole-foods, plant-based (4.5) and meat and seafood (4.1) were perceived the most nutritious, while cultivated protein (3.3) was perceived the least nutritious. In terms of environmental impacts, meat and seafood were rated the least environmentally friendly (1.5), while whole-foods, plant-based protein was rated the most (4.2). Processed, plant-based (3.8) and insect (3.7) proteins followed closely behind whole-foods, plant-based protein, followed by cultivated protein (3.4). As for accessibility, due to the current lack of and low availability of insect protein and cultivated protein, both were rated least accessible (1.1 for insect protein and 1.2 for cultivated protein). Whereas, meat and seafood were rated most accessible (4.8), followed by whole-foods, plant-based (4.2) and processed, plant-based (3.8).

Appendix 5: List of key actors involved in the alternative protein ecosystem

Table 23: List of key actors[9]

Organisation Type	Organisation Name
Ministries and statutory boards	• Ministry of Sustainability and Environment (MSE) and its statutory board: - Singapore Food Agency (SFA) • Ministry of Trade and Innovation (MTI) and its statutory boards: - Economic Development Board (EDB) - Enterprise Singapore (ESG) - Agency for Science, Technology and Research (A*STAR) - Jurong Town Corporation (JTC)
Research and education institutes	• Agency for Science, Technology and Research (A*STAR) and its corresponding sub-institutes: - Singapore Institute of Food and Biotechnology Innovation (SIFBI) which synthesises the research capabilities of A*STAR in areas such as agri-food, safety, biotechnology and nutrition. - Institute of Bioengineering & Nanotechnology (IBN) which develops microcarriers, edible plant-based scaffolds and culturing fish fat-derived stem cell lines for use in cultivated protein components. - Bioprocessing Technology Institute (BTI) which has already developed strong research capabilities that are easily transferrable to further the knowledge in alternative proteins. • The Department of Food Science and Technology at the National University of Singapore (NUS FST) • The Food Science and Technology Programme at the Nanyang Technological University (NTU FST) • NTU FRESH • The Food Technology Programme at Singapore Institute of Technology (SIT) • Food Innovation and Research Centre at Singapore Polytechnic (FIRC)
Shared Facilities and Pilot Plants / Innovation Centre	• FoodInnovate and its network of shared facilities: - Food Innovation and Research Centre at Singapore Polytechnic (FIRC) - High Pressure Processing (HPP) Resource Sharing Facility established by FIRC, ESG and Warehouse Logistics Net Asia (WLNA) - Shared Production Facility by ESG, JTC and SIT • Bühler and Givaudan Innovation Centre • A*STAR Perfect Day Joint Lab • ADM Plant-based Innovation Lab • Avant Meats R&D and pilot production facility • Food Tech Innovation Centre by Temasek and A*STAR • Agri-Food Innovation Park (AFIP) • Firmenich Culinary & SmartProteins Innovation Hub
Investors/ Venture Capital Firms	• Temasek • DSG Consumer Partners • Germi8 • ID Capital • Makana Ventures • VisVires New Protein • SEEDS Capital • New Crop Capital • SHIFT Invest • CPT Capital • AgFunder • Capital V • Blue Horizon • Food Ventures • VegInvest
Accelerators	• Big Idea Ventures • GROW

[9] The table does not illustrate all but only key, relevant actors.

	• Hatch • Innovate 360 • Trendlines Agrifood Innovation Centre (AFIC) • The Yield Lab
Alternative Protein Start-up (Plant-based)	• Karana • Beyond • Impossible • Omni Foods • Phuture Foods • Growthwell • Life3 Biotech • Next Gen
Alternative Protein Start-up (Cultivated)	• Eat Just • Shiok Meats • Ants Innovate • Gaia Foods • Cellivate Technologies
Alternative Protein Start-up (Fermentation-based)	• Sophie's Bionutrients • Mycovation • Quorn
Alternative Protein Start-up (Insect-based)	• Asia Insect Farm Solutions (AIFS)
Co-manufacturers	• SG Protein • SingCell
Incumbent Food Processing Companies/ Meat Producers	Local Examples: • Tee Yih Jia • SATS Ltd and its subsidiary, Country Foods Global Examples: • Tyson Foods • Cargill • Unilever • Ayam • Sodexo • Nestle
Non-Profit Organisation	• Good Food Institute (GFI)

(From Enterprise Singapore and Foodvalley NL, 2020)

Appendix 6: List of quotations for indicator P1

Table 24: List of quotations for indicator P1 - adequacy of governmental funding

Adequate	
R4	*"There is some financing where we put in, whereby we co-invest with companies. And then of course you have the likes of your Temasek also taking a strategic investment, interest. We do support companies and a bilateral basis, let's say we put in grant programs. But these run on a perennial basis. So, there are no plans to increase, nor decrease funding in this space, so to speak. Our research funding is done in five-year tranches. As part of the last 5-year tranche, we announced around S$144 million for Singapore Food Story R&D Programme. For the next 5 years tranche, there will be funding for this series, but it hasn't been publicly announced"* *"We have several pockets now right. So, the seed stage, we are probably talking to some of the accelerators in Singapore which most likely have co-investment partnerships with ESG. But that is at the pre-seed, seed stage. And then you've got Temasek that's also doing venture investments as well."* *"Some or most start-ups are supported by government. We won't support everyone, it's impossible. Maybe the way I would say is that there are funding programs out there to support the enterprise development of some of these star-tups."*
R12	*"Singapore Food Story R&D program (a national R&D program in the public sector) with total size of S$144 million. It was conceptualised about five years ago, but they only launched it in 2019. We have 3 themes; first theme is urban farming, then its food safety. The third theme is alternative proteins and that's slightly more than half the budget… So, the S$144 million is only for R&D. We also have tax incentives and other grant mechanisms done by EDB ESG and SFA. These are all public information company can apply to. In these agencies typically they would say I will allocate this budget for this particular. Agri food has its own budget. Total sum, I don't have that information. On the other hand, whether if you consider it public or private money, it's our sovereign wealth funds. So GIC and Temasek. Temasek is a lot more aggressive in terms of investing in the food space. So, if you follow them, you can see where Temasek has been investing in."* *"We talked about money in the public sector and sovereign wealth fund but there's also money in the private sector. So, the private sector we are attracting a lot of VCs and accelerators recently. So that's a joint effort between EDB and ESG. EDB has its own venture arm called EDB and ESG's seed capital. So, all these people provide certain government matching to their investments so that they invest in Singapore, but at the same time they also provide some tax incentives for certain, venture capitalists who are not part of the joint venture to actually put more of their money here."*
R14	*"And these companies are aware that the government here is putting a lot of money and efforts into this space, so they do reach out to us, they know we are putting together specific programs. So, for example for cultivated protein, the most recent round of grants, Singapore's largest and only cultivated protein R&D program was set up through this fund called the industry alignment fund. We won S$11 million. This was awarded in March of this year, so that one pulls together all the expertise across all of Singapore, not just A*STAR but also from other organisations, such as SIT. It's called CRISP, which stands for Centre for Innovation for Sustainable banking and Production of cultivated proteins. It's the kind of the one-stop shop for cultivated protein R&D."* *"So, we really identify these companies based on how much they have raised because that also tells us that all these VCs or investors are looking at these companies and have identified that they have certain technology that's very valuable. We look at their members in the group e.g. how big the R&D team is."*
Inadequate/restrictive/coupled with other issues	
R5	*"There is definitely some funding available - we are a Singaporean company, but the founders are foreign and that really restricts and limits a lot of the funding that we have access to. So that's been quite disappointing for us. So, I think there's definitely a lot more room for more funding and more flexible funding. A lot of the funding is quite very structured, and with start-ups that creates a challenge as well. Having to fit into a very specific project a lot of times but funding that goes into R&R in a start-up is exploring various different ideas at once so I think a more flexible funding model would be very helpful for the sector in Singapore."*

R6	*"You know among all the Asian countries, Singapore government by far is the best. They have done a lot of support, given a lot of money to this new food tech sector, no doubt. But when you compared to other governments around the world, especially the government in North America and Europe, Singapore government is still doing far, far less than those governments. Let me give you one example, two of our competitions are from Canada they each got like US$20-30 million from the Canadian government. Whereas in Singapore, the amounts are in hundreds of thousands or about S$1 million."* *"The government is actually doing quite a lot of things to encourage the local Investment communities to invest in food tech. Just to give you an example, Temasek spun off a few small VCs dedicated to early-stage investments, especially in the food and agri tech. So that's good news, but then again like I said, if mentalities (with regards to how sustainability is not a priority) are not changing, doing these organisational changes are not going to help, so the mentalities may take some time to make that shift."*
R8	*"Singapore Government has put a lot of resources, but the grant itself is not enough. I'm sure it will continue to grow, depending on the research performers capability to utilise the fund, and I think the government in general is cautious, because they have to be responsible for taxpayers' money to be used in good ways. I'm sure (the funding/support) will grow but whether it is enough to grow the sector, it is not enough"* *"I think for the cultivated protein area, people do complain a bit about the size of the grant. But it's nobody to blame, because if larger grant needs to be given, track record needs to be demonstrated. Public space research funding - there's no lack of it. But the private space research funding is insufficient."* *"I'm glad that some foundations like Amazon Foundation has come up with certain funding to support private space. Temasek funding is good to be used to support R&D space in the private space, whereas ESG funding is based on reimbursement basis. From public sector perspective, it's good management. But from private company perspective, it's a little bit more troublesome because you need to get your funding to spend on R&D first and then you claim it back, which takes a month"* *"All the private companies, the driver is usually by private investors. But there's an ecosystem support from the public funding to the companies such as through but there is insufficient support for private companies' R&D efforts. I won't say that there isn't, it's just hard to use. It takes a long time to get as well. The speed of getting the public funding for private company's R&D effort is usually discouraging"* *"It's easier to use VCs. There is a SBIR scheme in the US- small business, innovation, research which is public funding to support private company is doing R&D. Singapore has a similar scheme, but the size and scale tend to be small. And, most of the public funding stays in the public sector."*
R9	*"State funds? Not at this stage. Government is not willing to fund yet…Yeah, those are usually for established companies, not for start-ups. Even for start-ups, the money is so little and negligible. But for big, established companies, then they definitely will put in more funding support"*
R11	*"In terms of the grants that are publicly announced for Singapore, it's mostly targeted at academic groups, not so much for start-ups… I mean I would say that there are opportunities, but in some sense, if you are looking for investment funding for deep tech in Singapore, be it government or general private funding, it's just not so easy in the early stages. Most of them will have to enter some kind of accelerators to get some early grants to start."*
R14	*"There is definitely need for more, more public funding. It is one of the highest priorities for us as an organisation to drive more public funding. And even though Singapore is doing a lot for a very small country but in numbers, it is obviously a small player because it's such a small country, right. If you look at for example how fast the vaccines were developed and the clean energy sector, if governments really put money behind the sector, it can suddenly grow much faster than you expect right. We see this happening in Singapore, there is definitely room for more… If you look at China, or EU or US, the government put in billions, and not a million here or S$500,000 into this start-up. It's like, okay, we're going to dedicate a billion of our annual budget towards a research centre for alternative proteins or whatever. So, we really wish to get governments to include alternative proteins as a part of their environmental solutions."*
R15	*"What I've seen sometimes with grants for example grants are always based on pre-approved solutions. If you have pre-approved solutions, you can't do innovation. If you do something different than anyone else, you don't get a grant for it."*

Appendix 7: IHS copyright form

In order to allow the IHS Research Committee to select and publish the best UMD theses, participants need to sign and hand in this copy right form to the course bureau together with their final thesis.

Criteria for publishing:

1. A summary of 400 words should be included in the thesis.
2. The number of pages for the thesis is about 50.
3. The thesis should be edited

Please be aware of the length restrictions of the thesis. The Research Committee may choose not to publish very long and badly written theses.

By signing this form, you are indicating that you are the sole author(s) of the work and that you have the right to transfer copyright to IHS, except for items cited or quoted in your work that are clearly indicated.

I grant IHS, or its successors, all copyrights to the work listed above, so that IHS may publish the work in *The IHS thesis series*, on the IHS web site, in an electronic publication or in any other medium.

IHS is granted the right to approve reprinting.

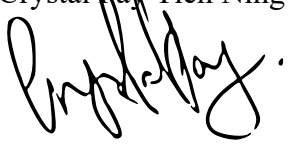
The author(s) retain the rights to create derivative works and to distribute the work cited above within the institution that employs the author.

Please note that IHS copyrighted material from *The IHS thesis series* may be reproduced, up to ten copies for educational (excluding course packs purchased by students), non-commercial purposes, providing full acknowledgements and a copyright notice appear on all reproductions.

Thank you for your contribution to IHS.

Date : 31st October 2021

Your Name(s) : Crystal Ray Tien Ning

Your Signature(s) : 

Please direct this form and all questions regarding this form or IHS copyright policy to:

The Chairman, IHS Research Committee Burg. Oudlaan 50, T-Building 14th floor, 3062 PA Rotterdam, The Netherlands	j.edelenbos@ihs.nl Tel. +31 10 4089851

Institute for Housing and
Urban Development Studies of
Erasmus University Rotterdam