The Paradoxical Economy of Food Waste Prevention

A Study of Systemic Food Waste Prevention as a Transition Pathway to Sustainable Food Systems

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Abstract

The global food waste problem is commonly linked to sustainability challenges such as climate change, resource depletion and the dysfunction of discarding large amounts of food despite the prevalence of hunger. As such, food waste reduction has become a key objective within the United Nations sustainable development framework, with a goal to halve food waste by 2030.

Despite this recognition of food waste as a significant issue for sustainable development, food waste, as a distinct field of scholarship, has not received much attention in wider food systems research proportionate to its scale. Addressing this research gap, this thesis by published papers offers a system-based understanding of food waste. Starting from an analytical review of dominant global discourses of food waste and its prevention, this work identifies a 'prevention paradox', which hampers prevailing prevention approaches due to their failure to account for the systemic nature of the food waste problem. Subsequently, an empirical exploration of the systemic causes of food waste presents findings from the Australian horticulture industry that allow for an account of the interconnected processes that underpin waste creation along the whole food supply chain. The explanation of systemic food waste including its theoretical significance for sustainable food systems is grounded in a socio-technical transitions perspective and extends transition studies to horticultural food waste and agrifood systems.

Theoretically, this research positions systemic food waste as a symptom of food system 'lock-in' into a deeply ingrained cultural, regulatory, material and economic reliance on unsustainable overproduction and food surplus. Accordingly, interventions targeting the systemic prevention of food waste emerge as pathways to transform broader food system characteristics toward greater sustainability. These findings translate into some key recommendations for industry, policy and research: that a systems approach is essential to unlocking food waste prevention, that the identification of lock-in dynamics exposes new avenues for food waste prevention, and that measurement and disclosure protocols need to make aggregate surplus visible across the whole supply chain.

Key Words

Systemic Food Waste Prevention; Food System Lock-In; Transition Management; Prevention Paradox; Surplus-to-Waste Lock-In; Aggregate Resource Use

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List of Abbreviations

EU:	European Union
EC:	European Commission
FAO:	Food and Agriculture Organisation
FMCG:	Fast Moving Consumer Goods
FUSIONS:	Food Use for Social Innovation by Optimising Waste Prevention Strategies
GDP:	Gross Domestic Product
GHG:	Greenhouse Gases
MLP:	Multi-level Perspective (Socio-technical Theory)
NFF:	National Farmers' Federation
NGO:	Non-governmental Organisation
RQ:	Research Question
SDG:	Sustainable Development Goals
STRN:	Sustainability Transitions Research Network
UN:	United Nations
UNEP:	United Nations Environment Programme
WRAP:	Waste and Resource Action Programme
WRI:	World Resource Institute

Glossary

Key Terms	*Definitions*
Adaptive Theory	A methodology of social research aiming to explain rather than merely describe social phenomena. Adaptive Theory uses theory to guide the collection and analysis of empirical data and offers a set of practical instructions for researchers. Adaptive Theory draws on *Social Domain Theory* to generate explanation of social phenomena.
Aggregate Resource Use	The cumulative amounts of resources in use within a specific supply chain. This concept represents physical material flows as well as the accumulated resource inputs such as water, energy, fossil fuels, labour embedded in the physical materials. This concept is related to *Surplus Footprint*.
Coding: provisional / satellite / conceptual bridging	The three stages of the thematic coding process according to Adaptive Theory. Provisional codes emerge from empirical data or from prior theoretical concepts; satellite coding organises provisional codes into broader concepts, and conceptual bridging generates concept explanation by describing their relationships to *Social Domains*.
Destabilisation	A concept of *Socio-technical Transitions Theory* describing intentional or unintentional processes that erode and ultimately phase out established and dominant regime practices. Destabilisation focuses on regime inherent features of transitions rather than on transitions due to interaction between *regime* and *landscape* or *niches*.
Investigative Research	A research methodology proposed by Derek Layder (2018) that combines the epistemological framework of *Social Domain Theory* with *Adaptive Theory* as a theoretical and practical approach to social research.
Landscape	See *Multi-level Perspective*
Lock-In	A concept of Socio-technical Transitions Theory describing the stability and persistence of system/regime processes and characteristics due to existing technology, infrastructure, legislation, policy, cultural and ideological factors that constitute the status quo, seek self-reinforcement and cause resistance to change.
Multi-level Perspective	An influential theoretical perspective within *Socio-technical Transitions Research* that conceptualises transitions as interactions between regime, niche and landscape levels. Regimes represent dominant socio-technical configurations of existing systems including actors, infrastructures, norms, rules, technologies and

	practices. Niches refer to innovative emerging spaces that may challenge established regime practice. Landscapes describe the wider social background and context that influences regimes and niches through socio-economic, demographic, cultural and ideological factors.
Niche	See *Multi-level Perspective*
Overproduction (of food)	'Overproduction' refers to production amounts that contribute to oversupply and food surplus. Surplus is the amount of excess food flowing through supply chains, i.e. food in excess of household requirement or food exceeding the nutritional requirements of the population. 'Oversupply' is often used interchangeably with 'surplus' and refers to surplus becoming available in the market.
Prevention Paradox	The Prevention Paradox describes the perverse outcomes of food waste prevention interventions that promote waste creation rather than preventing it. Approaches to food waste prevention may inadvertently perpetuate, impede or exacerbate the food waste problem by targeting only proximate causes or by managing waste only after it has been generated rather than addressing the underlying systemic processes of waste creation.
Problem Sampling	A variant of 'purposive sampling' used in Adaptive Theory. Problem sampling targets respondents that are able to contribute to understanding the problem under investigation.
Process Theory vs. Variance Theory	Two key conceptions of causal explanation in social science. Process Theory proposes causal inference based on a convergence of patterns, sequences, mechanisms, or social structures that produce effects systemically and in accordance with causal principles. Variance Theory conceives of causal inference as a degree of co-variation between variables that have been operationally defined, controlled, manipulated and measured.
Regime	See *Multi-level Perspective*
Scope 3 emissions	'Scope 1-3' denote classifications of emissions related to business activities of corporations. Scope 1 emissions are related to activities under direct operational control, Scope 2 are the proportionally allocated emissions caused by third party energy providers, while Scope 3, by far the largest impacts, are the emissions generated from the usage of products. In the case of coal, Scope 1 and 2 emissions relate to the mining and supplying of coal, while Scope 3 emissions arise from the burning of coal.
Social Domains Theory	An epistemological framework to analyse and understand social reality. Social domains are pre-constituted and interrelated social structures of varying degrees of

	stability and transformative capacity. The work of Layder (2006, 2018), which informed the methodology of this thesis, describes four social domains: psychobiography, situated activity, social settings and contextual resources.
Socio-technical Transitions Theory	A conceptualisation of large scale systems providing services like energy, transportation or food production and their transition to sustainability (also termed 'sustainability transitions'). Environmental and social challenges are seen as derived from patterns of unsustainable production and consumption. Addressing these challenges requires profound transformational shifts of technology, infrastructure, politics and culture.
Surplus	See *Overproduction*
Surplus footprint	A concept related to *Aggregate Resource Use*. The surplus footprint describes the direct and indirect impacts of supply chain activities to overall food surplus flowing through supply chains. Accordingly, a high surplus footprint will contribute to elevated levels of aggregate resource use.
Surplus-to-waste Lock-In	A phenomenon that describes how existing food system infrastructures and processes are locked into systemic surplus creation, are unsuited to prevent surplus from going to waste and rather amplify and accelerate the transition from surplus to waste.
Systemic Food Waste Prevention	The systemic perspective perceives food waste as inherent or intrinsic to food systems, i.e. intentionally and unintentionally created through processes and characteristics of food systems. Food waste prevention, therefore, is conceived of as addressing food system processes and characteristics that cause waste. Systemic prevention also implies interventions that consider waste creation along the whole supply chain, not only at specific points, assuming that the causes for waste creation may originate at any point in food systems.
Transition Management	Transition management is a deliberative process to create a societal purpose/vision, movement, and direction facilitating and promoting transitions to sustainability. Also see *Socio-technical Transitions Theory*.

Statement of Original Authorship

The work contained in this thesis has not been previously submitted to meet requirements for an award at this or any other higher education institution. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made.

Signature: QUT Verified Signature

Date: 15 December 2020

Statement of Contribution of Co-Authors for Thesis by Published Papers

The authors listed below have certified that:

- they meet the criteria for authorship and that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
- they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
- there are no other authors of the publication according to these criteria;
  potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit, and
- they agree to the use of the publication in the student's thesis and its publication on the QUT's ePrints site consistent with any limitations set by publisher requirements.

This statement applies to the research papers included in this thesis and listed in Table 1 (see p.13):

Authorship	Contribution
Student Author: Rudolf Messner Signature: QUT Verified Signature	Conceptualisation, Investigation, Formal Analysis, Writing - Original Draft Preparation
Principal Supervisor Author: Dr Carol Richards Signature: QUT Verified Signature Date: 15 December 2020	Writing - Reviewing and Editing, Supervision
Associate SupervisorAuthor: Dr Hope Johnson Signature: QUT Verified Signature Date: 15 December 2020	Writing - Reviewing and Editing, Supervision

List of Papers and Conference Presentations

Table 1: Thesis papers overview and status

Paper Title (Authorship)	*Journal*	*Ranking*	*Status*
P1: The "Prevention Paradox": Food Waste Prevention and the Quandary of Systemic Surplus Production (R.Messner, C.Richards, H.Johnson)	Agriculture and Human Values (Springer Nature)	Scimago / Q1 Impact Factor: 2.442	Published: *22 January 2020*
P2: From Surplus-to-waste: A Study of Systemic Overproduction, Surplus and Food Waste in Horticultural Supply Chains (R.Messner, H.Johnson, C.Richards)	Journal of Cleaner Production (Elsevier)	Scimago / Q1 Impact factor: 7.246	Published: *01 September 2020*
P3: Systemic Food Waste Prevention as a Transition Pathway to Sustainable Food Systems (R.Messner, H.Johnson, C.Richards)	Journal of Rural Studies (Elsevier)	Scimago / Q1 Impact Factor: 3.544	*Submitted – under review*

Table 2: Other publications and conference papers

Paper Title	*Publication Outlet*	*Ranking*	*Status*
The Paradoxes of Food Waste Reduction in the Horticultural Supply Chain (C.Richards, B.Hurst, R.Messner, G.O'Connor)	Industrial Marketing Management (Elsevier)	Scimago / Q1 Impact Factor: 4.695	*Published: 13 December 2020*
Surplus Mechanics: Systemic Overproduction and Food waste Lock-In	Conference Presentation: Agri-Food XXVI Conference (01-05 December 2019) at University of Canterbury and Lincoln University (NZ)		
Food Waste Transitions from Visibility to Sustainability. Towards a Socio-Technical Theory of Food Waste Prevention	Conference Presentation: Agri-Food XXV (03-05 December 2018) at University of Queensland, Brisbane		
Does Food Waste Management Prevent Food Waste Prevention? A Review of Food Waste Prevention Research (R.Messner, C.Richards, H.Johnson)	Peer Reviewed Conference Proceedings Unmaking Waste (20-23 September 2018) at University of South Australia		*Accepted for publication*

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The completion of this research and this final thesis relied on many favourable circumstances, most importantly the kind and indispensable support I received from many others. The writing of a PhD thesis is often likened to a long and arduous yet worthwhile and rewarding journey. A famous saying goes, “Even the longest journey begins with the first step”. My first step was meeting my principal supervisor Dr Carol Richards, without whom this project would have never been started, let alone completed, and Dr Hope Johnson, my associate supervisor. The years of exploring and investigating the paradoxical and wicked problems of food waste together, learning and developing my research skills and sharing highly inspiring and equally enjoyable collaborations on a number of publications were a true privilege and a real joy. Professionally, I would like to acknowledge Carol and Hope for their masterful and invariably positive and encouraging supervision of my candidature and, personally, I simply want to express my deep gratitude for a journey together that never felt arduous or long.

Arriving in Brisbane with my family after spending most of my adult life working in industry rather than academia, and living in China rather than Australia, was a major life change. Going forward to school, QUT proved to be a most welcoming and supportive environment for my PhD journey. QUT generously provided me not only with a vast array of research, training and networking resources, including all funding for this research, but also an Australian Research Training Program (RTP) scholarship, which I would like to acknowledge with gratitude.

I would also like to express my gratitude to all research participants, who shared their time, experience and knowledge with me. Without their deep insights this research would never have seen the light of day. The many hours driving to or from interviews pondering conversations, exchanges and impressions were a truly valuable time for this research and for me personally. The papers in this thesis have been submitted for publication with a number of journals and presented at conferences. Paper Two was edited professionally prior to submission and additionally this thesis benefitted greatly from the knowledgeable and encouraging comments of anonymous reviewers, peers and colleagues and the evaluations and suggestions from panel members at my final seminar, all of whom I would like to acknowledge here anonymously and collectively.

Sensibly, I believe, there is no adage that “even the longest journey ends with the last step”. Rather, the end of a journey is more commonly imagined as the beginning of a new journey. *Food* is, profoundly and deeply, part of the human condition and experience and it should be an epitome of the good life of humanity. After these past years of learning about food waste and food systems, I am able to ask more and perhaps better questions now than at the outset. The research journey is thus continuous, a process of learning, seeking and evolving new ideas, always hopeful that one way or another, they might contribute to a healthier, better and more sustainable life.

1. Introduction

The food waste problem has emerged as a contemporary grand challenge and social dilemma sitting at the intersection of the three mega-issues of climate change, natural resource use, and global hunger. The growing amount of literature and reports on food waste indicates an overarching consensus on the importance and gravity of the problem and the formidable threats it poses to society, economy and the environment. Food waste as an issue has attracted the attention of national and international regulation, corporate social responsibility programs, and scholarly research. These spaces of activity have established widely shared and agreed upon explanations regarding the practices and circumstances that contribute to food waste and proposed various approaches of food waste prevention (FAO, 2011; Fusions, 2016, WRAP, 2018). A closer examination of dominant approaches to food waste prevention, however, reveals an underlying 'paradoxical economy' that is characterised by conceptual and practical uncertainties concerning the nature of the food waste problem and the purpose of food waste prevention itself. The various ambiguities and dissonances surrounding the problem of food waste prevention are the source of the original inspiration and the starting point of this research.

A 'paradox' has been defined as "a situation or statement that seems impossible or is difficult to understand because it contains two opposite facts or characteristics" (Cambridge Dictionary). Accordingly, a 'paradoxical economy' is a system characterised by contradicting understandings, purposes and objectives. This thesis considers food waste prevention as an example of a paradoxical economy. Food waste has, for instance, been commonly framed as an economic problem, specifically "costing economies around the world billions of dollars" (Australian Government, 2017; FAO, 2019a; Jurgilevich et al., 2016). Yet food waste creation as well as its disposal are both part of an economic value chain and represent tangible and substantial economic activities and interests, which appear to be in a fundamental economic conflict with efforts to reduce, prevent and eliminate food waste. Food value chains, from growing food to its disposal as waste, have evolved over time with significant capital investments, technological developments, stakeholder commitments and public regulatory support as inherently waste creating material economic infrastructures. The substantial interests vested in these

infrastructures and their conflict of interest with food waste prevention represent important contradictions at the heart of the food waste prevention issue and have been significant in shaping practices and responses of food waste prevention across developed economies (Cloke, 2016; Gille, 2012; Hutner et al., 2017; Zacho and Mosgaard, 2016).

Another dissonance of food waste prevention arose from dominant discourses that have commonly perceived 'food waste prevention' as interventions into proximate food waste causes with the aim of diverting or averting waste. In this conception, food waste does not greatly differ from other kinds of waste requiring management. As such, by addressing existing food surplus and waste material and targeting its *management and disposal*, food waste prevention has come under the purview of waste management, which considers prevention as the highest policy priority (Van Ewijk and Stegemann, 2016). Such a framing of prevention as part of waste management, however, places boundaries around how society problematises and addresses food waste and its prevention. For example, perceiving food waste prevention as waste management considers interventions *post-hoc*, i.e. once food waste exists, which highlights the underlying contradictions and idiosyncrasies that arise from trying to prevent what already exists. Consequently, such 'prevention' is focused on the most efficient methods of recovery or disposal of the end-of-pipe waste material without addressing underlying processes and implicit incentives of waste creation and may thus lead to an increase rather than reduction of food waste (Mourad, 2016).

A prevailing approach to food waste prevention in research and practice has been targeting potential interventions *ad-hoc*, i.e. related to distinct points of the supply chain and reacting to distinct causes and events, to the potential detriment of other stages of the supply chain. In this regard, a dominant narrative has been framing food waste as a consumer and household problem and proposing food waste prevention predominantly as a series of interventions targeting individual behaviour change. Yet, such limited and targeted approaches might distract from interventions addressing the creation and production of waste within supply chains and may misconceive of the externalisation or diversion of waste to other points of the supply chain as genuine food waste prevention. Indeed, as this thesis will

demonstrate, within the paradoxical economy of food waste prevention, ad-hoc, post-hoc and end-of-pipe approaches have remained dominant conceptions of 'food waste prevention' globally.

To overcome the conceptual ambiguities and inherent contradictions of food waste prevention, researchers have proposed a system perspective of food waste, conceiving of food waste as a problem along the whole supply chain and linked to underlying fundamental system characteristics and processes (Göbel et al., 2015; Hodgins and Parizeau, 2020; Mourad, 2016; Redlingshöfer et al., 2020; Thyberg and Tonjes, 2016). Corvellec et al. (2018) argued that "waste prevention is not about waste", rather it requires a change of practices and processes at every step along the value chain to prevent the creation of waste. Such change is conceived of as deep *systemic change* to achieve a transformation of prevailing waste producing systems by focusing food waste prevention primarily on the processes that create food waste rather than the waste itself.

The system perspective perceives food waste as an intentional or unintentional outcome of food system processes, and an embedded component of unsustainable practices of production and consumption. Accordingly, as part of a wider conception of sustainable development, food waste has been incorporated into the United Nations Sustainable Development Goals (SDG), specifically Goal 12, 'Responsible Consumption and Production' (WRI, 2016). However, despite the growing global awareness around food waste and its scale as a major sustainability challenge, the systemic perspective that links food waste creation empirically and theoretically to broader food system characteristics and processes has not been widely considered in food system research. Indeed, as the literature indicates, the key processes and in-depth mechanisms of food waste creation as well as the theoretical significance of food waste for food systems have been under-researched and represent important knowledge gaps in emerging food waste research (Bengtsson et al., 2018; Hodgins and Parizeau, 2020; Redlingshöfer et al., 2020). Addressing these gaps, the objective of this thesis is to make a contribution to a systemic perspective of food waste by demonstrating its theoretical significance for sustainable food systems.

To explore the systemic nature of waste creation along food chains this research determined a range of specific food system activities and characteristics as the subject matter of the empirical inquiry. An emerging focus within food waste research has been highlighting 'overproduction' and 'food surplus' as possible structural causes of food waste (Chaboud and Daviron, 2017; Mourad, 2016; Papargyropoulou et al., 2014; Pedersen et al., 2015; Salemdeeb et al., 2017; Vulcano and Ciccarese, 2017). Specifically, food waste research positions overproduction as a fundamental characteristic of food chains and systems that, in combination with other factors, leads to food surplus that turns to waste. Due to its focus on production, this research chose primary production, specifically the Australian horticulture supply chain, as the setting of the qualitative empirical research investigating food waste and its relationship to overproduction and food surplus. To explore and understand related processes, practices and characteristics of horticultural production, the empirical study included 29 industry experts in a series of semi-structured interviews.

Beyond the empirical study on food system processes related to waste creation, this thesis offers a theoretical perspective of systemic food waste grounded in the theory of socio-technical transitions to sustainability (Geels, 2011; Köhler et al., 2019). The choice of this theoretical approach was motivated by two distinct advantages of applying a socio-technical framework. Firstly, it enables an interpretation and conceptualisation of the research findings as phenomena related to specific system-inherent socio-technical characteristics and processes. Secondly, having apprehended food waste in relation to socio-technical systems, transitions theory, as a widely acknowledged research tradition, enables theorising on system transformations towards greater sustainability, including the transformation of characteristics and processes causing or relying on food waste creation. Specifically, this thesis explains food waste creation through a lens of 'food system lock-in' into unsustainable practices of production and consumption, while food waste prevention theoretically represents 'escaping lock-in' by identifying transition pathways to sustainability.

The in-depth account of the systemic nature of food waste creation and especially its proposed theoretical understanding as an inherent feature of locked-in food system processes makes a

significant and original contribution to the discipline of food waste research. Specifically, this thesis addresses a number of research gaps in current food waste research, including the in-depth understanding of systemic food waste creation, the explanation of overproduction and surplus as a cause of food waste, the generation of food waste in primary production and the broader theoretical significance of food waste for food systems. In doing so, the thesis is structured as follows: The remainder of the introduction chapter outlines the research problem and research questions, while also introducing the theoretical framework applied in this research, socio-technical transitions to sustainability. This work is a thesis by publication and consists of three papers, which represent the output of this research. The introduction chapter sets out how the three published papers are connected to the same research program. Following the introduction, the second chapter of this thesis outlines the qualitative methodology deployed in the Australian horticulture industry to answer the research questions, including the underlying epistemological assumptions as well as the detailed methods of data sampling, collection and analysis using Adaptive Theory and Social Domain Theory as guiding methodological frameworks. The chapters three to five consist of the three papers that have either been published or submitted for publication. The first paper (Paper One) was published as a discussion paper and represents a literature review while Paper Two and Three present empirical and theoretical findings as well as conclusions of the empirical research in horticulture. The thesis concludes with a statement of contributions, limitations and implications for food waste research and practice. The next section reviews key publications and literature in order to highlight the research gaps and to justify the research questions.

1.1 Systemic Food Waste: Literature Review and Research Problem

Food waste has evolved into a global mega-challenge to environmental, economic and social sustainability. Prevailing food systems rely on processes and characteristics that lead to discarding, depending on the measurement protocol deployed, 30-80% of food mass and nutrition value (Alexander et al., 2017; FAO, 2019a; Vulcano and Ciccarese, 2017; WRI, 2019). This high volume of waste is of concern due to the dual impacts of food waste in terms of loss of natural resources that become

embodied in the food through the process of its production, as well as the negative environmental impacts of food waste management and disposal. Indeed, global food production contributes an estimated 14-29% to greenhouse gas GHG emissions worldwide, and is also one of the main human activities causing the unsustainable and intensive depletion of vital resources, such as forests, water, soils, non-renewable energy, and biodiversity (FAO, 2014; Hoekstra, 2012; Kummu et al., 2012; Lundqvist et al., 2008; Springmann et al., 2019). Besides the negative resource impacts of food production up to the point where it becomes waste, the process of management and disposal of food waste has been linked to significant additional negative impacts in terms of emissions (Porter et al., 2016; Vermeulen et al., 2012), resource use (Kibler et al., 2019; Vittuari et al., 2016) and economic cost (Jurgilevich et al., 2016; Stenmarck et al., 2011) for the sole purpose of managing and disposing the waste material. In the meantime, food insecurity remains a major global issue that is centred around inadequate access to nutrition alongside the long-term threats to food security posed by resource degradation and climate change (FAO, 2019b; Friel et al., 2014; Springmann et al., 2019).

There is now a burgeoning literature on the causes and solutions to food waste. Despite the seeming intractability of the food waste problem, its context-specific causes are largely agreed upon and have been comprehensively studied. Systematic inventories pinpointing hundreds of single food waste causes have been presented in official publications by government, non-governmental organisations (NGOs) and international agencies. Key bodies synthesising and disseminating the proximate causes of food waste include the Food and Agriculture Organisation (FAO, 2011), the United Nations Environment Programme (UNEP, 2015), the NGO Waste and Resources Action Programme (WRAP, 2018), and the European Commission's Fusions project (FUSIONS, 2016). Additionally, a growing body of scientific literature has exhaustively documented the wide-ranging causes of food waste along the food supply chain. These causes include disruption by unpredictable events such as changes in demand, inefficiencies in manufacturing processes, lack of coordination among supply chain actors, food degradation during transportation, food standard regulations, and commercial practices of excessive demand stimulation through aggressive marketing practices (Alexander et al., 2017; Bernstad et al., 2017; Canali et al., 2013; Devin and Richards, 2018; Muriana, 2017). The

establishment of the “Food Loss and Waste Protocol” (WRI, 2016), as a global multi-stakeholder framework, represented a significant step towards harmonisation of various food waste definitions, standards and reporting guidelines.

Within the more specific debates about causes, definitions and measures of food waste, broader conceptual and practical dissonances become evident, in part, because of the pervasive role of food waste in a diverse number of sustainability issues from sustainable food production, food security, social welfare and health through to climate change and ecosystem services (Ericksen et al., 2012; FAO, 2019a; Göbel et al., 2015; Lemaire and Limbourg, 2019). Research has highlighted how food waste definitions are underpinned by normative and political motivations and preferences (Corrado et al., 2019; Chaboud and Daviron, 2017; Koester, 2014) as well as by processes of social construction that determine what a society considers “waste” (Gille, 2012). How food waste is defined, classified and measured changes how the problem of food waste is understood, compared and addressed. Some areas of inconsistency have been discussed and highlighted in extant research. For example, food waste protocols in the EU measure food that is thrown out by consumers, retailers or producers but do not measure food diverted to animal feed. Thus, little is known about how much food is diverted to animal feed, and how much of this food/feed that is intended for humans is then consumed by non-human animals (Corrado et al., 2019, p.94). Similarly, food surplus and waste in primary production diverted to animal feed is not classified food waste (Hartikainen et al., 2018, p.502), neither is crop ploughed in prior to harvest, which is not yet considered ‘food’ (Schneider et al., 2019, p.107). As such, key waste streams diverting food from human consumption, are not necessarily within the purview of food waste measurement or prevention.

By contouring food waste accounting in these ways, it is difficult to obtain a complete idea of how much food is produced for humans and then not actually consumed by humans. A lack of knowledge about the extent of the problem prevents discussion about how to respond to food waste’s various other, interrelated dimensions including: the adverse dietary and environmental impacts of livestock production (Alexander et al., 2017; Kummu et al., 2012); the desirability of biofuel production over other

renewable energy sources in terms of environmental impacts (Götz et al., 2017; McMichael, 2010) and the problem of the overconsumption of food associated with the prevalence of diet-related non-communicable diseases worldwide (Alexander et al., 2017; Banwell and Dixon, 2013; Papargyropoulou et al., 2014; Hall et al., 2009; Smil, 2004; Vandevijvere et al., 2015; Vulcano and Ciccarese, 2017). By isolating food waste from other activities affecting food system sustainability, the strategies open to decision-makers in preventing food from existing only to be wasted are significantly reduced. From a food system perspective, therefore, a broader and more inclusive definition of food waste beyond too detailed taxonomic distinctions has been considered helpful (Hodgins and Parizeau, 2020, p.43). A common and very broad understanding of food waste is "the removal of materials intended for human consumption from the food supply chain" (FAO, 2019a). For the purposes of this research, therefore, our attention is focused on the sustainable use of resources that go into producing and processing food that is either not eaten or not needed to be eaten by humans.

1.1.1 Narratives of Food Waste

Scholarship on food waste has made vital contributions to understanding the extent of the problem of food waste and/or the role of consumer behaviour as a cause of food waste (Aschemann-Witzel et al., 2015; Principato et al., 2018; Schanes et al., 2018; Stancu et al., 2016). Consumer and household food waste have been singled out due to their position at the end of the supply chain and the cumulative effects from production, transportation, storage, and retail, suggesting a higher environmental impact compared to products wasted earlier in the supply chain (Bernstad et al., 2017; Williams et al., 2012). There is also an intuitive plausibility attached to the perception of waste as an unavoidable side effect of eating, something *all* humans do (Evans et al., 2012). The strong emphasis on consumers and households as the key to solving the food waste problem is prominent in food waste discourses, but it is by no means universally accepted. Researchers have argued that the social and material conditions of food consumption and the impacts of prevailing food systems on consumer behavior need to be taken into account as well (Chaboud and Daviron, 2017; Evans, 2011). Indeed, research has highlighted how a substantial part of consumer waste is generated by practices upstream, such as packaging,

promotional offers, and restaurant portions sizes, as well as deeply engrained consumption habits such as increased fast food consumption and overprovisioning that have been shaped by the structure and evolution of the food supply chain (Butler and Dixon, 2012; Evans, 2011; Mourad, 2016; Mylan et al., 2016). This perspective indicates that food waste creation at household level cannot be explained by consumer behavior as a sole cause, but has to be regarded within the structural context of the whole food supply chain.

The literature identified how surplus and waste may occur at all stages of the food supply chain including farming, manufacturing, logistics, retail, and food service (Alexander et al., 2017; Bernstad et al., 2017; Göbel et al., 2015; Stenmarck et al., 2011). The causes are related to management inefficiencies, such as errors in production planning, inventory management, and packaging and labelling, which cause otherwise perfectly edible food to become waste (Garrone et al., 2016; Mena et al., 2011). Researchers and practitioners regard food waste prevention in supply chains as an issue requiring improved management efficiencies, such as the ability to minimise surplus food, and the ability to prevent surplus food from turning into waste (Canali et al., 2013; Garrone et al., 2014, 2016; Midgely, 2013).

Some dominant approaches to food waste have focused on the recovery of value from existing food surplus and waste material, such as re-distribution, recycling or transforming food waste into energy (Eriksson, et al., 2015; Eriksson and Spångberg, 2017; Garrone, et al., 2016; Kirchherr et al., 2017; Raak et al., 2017; Zaman, 2015). Preventing surplus from going to waste and preventing organic waste from entering landfill by identifying ways of re-use addresses some of the highly negative environmental impacts of food waste. Yet, these approaches have significant trade-offs and barriers to development. Re-use or value-adding does not have the potential to prevent the consumption of energy, water, packaging and other resources, as well as direct and indirect waste impacts such as packaging, effluents and the greenhouse gas emissions associated with production, transportation, storage, and preparation of food (Hoekstra, 2012; Kummu et al., 2012; Quested et al., 2013; Vermeulen et al., 2012).

These resource impacts become virtually embedded in food waste and, critically, are not recoverable through re-use or value adding (Cuellar and Webber, 2010; Vittuari et al., 2016).

Furthermore, food waste treatment and recovery require costly infrastructure, technology, economies of scale, investment, and expectations of returns. They do not, however, reduce the amounts of food waste generated but a conceptual shift here sees waste no longer as an output or externality but as a resource and input into value creation. The technological and commercial optimism of creating a business around food waste may thus even contribute to more waste (Corvellec et al., 2012, p.302; Evans et al., 2012, p.22). Strictly speaking, the waste transformation approach is really an approach to food waste disposal and conversion rather than food waste prevention in terms of addressing the processes of waste creation. As such it could be a distraction from food waste prevention by promoting competing methods or even a hindrance of food waste prevention by committing long term investments to waste transformation or disposal infrastructures (Mourad, 2016; Corvellec et al., 2012).

Conceptually and practically, the existing dominant approaches to food waste focus on distinct points in the supply chain, such as consumers, or, as end-of-pipe solutions, address the material food waste itself, rather than the processes that gave rise to it. Two key problems remain: The meaning of ‘prevention’ in these contexts is conceptually ambiguous and may refer to or justify a wide range of activities and responses (Redlingshöfer et al., 2020; Van Ewijk and Stegemann, 2016). Secondly, the act of preventing food waste creation is significantly different in nature to the act of dealing with existing waste (Corvellec et al., 2018; Zorpas and Lasaridi, 2013). Both problems highlight the need for comprehensive reflection on the concept of food waste prevention, to understand ontologically and normatively what is being wasted, who is wasting, and what the nature and purpose of food waste prevention might be (Savaget et al., 2019).

1.1.2 The System Perspective: Overproduction and Food Waste

Trying to overcome these conceptual dissonances of food waste prevention, a growing body of food waste scholarship takes a different approach. It conceptualises food waste from a system perspective as embedded in, and as an outcome of, complex, non-linear production and consumption dynamics (Mourad, 2015; Göbel et al., 2015; Redlingshöfer et al., 2020; Thyberg and Tonjes, 2016; Urrutia et al., 2019). The system perspective considers food waste as occurring along the whole food chain, due to "causes and effects that may originate at different stages of the food chain, therefore neither caused by a single culprit, nor subject to a single solution" (Göbel et al., 2015, p.1429). As such, systemic food waste prevention does not seek narrow responses to the material waste alone (Hamilton et al., 2015; Sala et al., 2017) or ad-hoc solutions that may intentionally or unintentionally externalise food waste to other parts of the supply chain or society (Chaboud and Daviron, 2017; Clapp, 2014; Parker and Johnson, 2019), but targets the mechanisms of food waste creation embedded in system processes, characteristics and activities and their wider impacts within food systems (Corvellec et al., 2018).

An emerging focus within food waste research has been highlighting 'overproduction' and 'food surplus' as possible systemic causes of food waste (Chaboud and Daviron, 2017; Mourad, 2016; Papargyropoulou et al., 2014; Pedersen et al., 2016; Vulcano and Ciccarese, 2017). While research has considered some forms of surplus as aberrations and errors of food production (Garrone et al., 2016; Raak et al., 2017), others have emphasised the systemic nature of overproduction and surplus as structural food system phenomena (Mourad, 2015). Indeed, the overproduction of food has received wide attention in food systems and food regime research, generally with an emphasis on agricultural dumping, food aid, free trade and geopolitics (Clapp, 2014; McMichael, 2009). Research has described chronic and systemic food surplus created by technological advances, cheap fossil fuels, sustained public subsidies, and concentrated industrialisation as dominant characteristics of prevailing food systems (Bjørkhaug and Richards, 2008; Carolan, 2018; Rosin et al., 2012; Weis, 2007). Rather than a failure or inefficiency, systemic overproduction has been considered normal and simply "part of the system" (Mourad, 2016, p.469) and described as related to the "impressive growth of productivity in the

agricultural sector" (Canali et al., 2013, p.17). Accordingly, surplus has come to represent a fundamental condition of industrialised food systems.

Research has also observed apparent correlations between overproduction, food surplus and food waste, arguing that overproduction contributes to overconsumption, diet related non-communicable diseases, as well as increases of food waste (Friel et al., 2014; Hall et al., 2009; Hic et al., 2016; Vandevijvere et al., 2015). Accordingly, some researchers have proposed the reduction and prevention of large-scale food surpluses as a potential strategy of systemic food waste reduction and prevention (Papargyropoulou et al., 2014, p.112; Pedersen et al., 2015, p.5; Vulcano and Ciccarese, 2017, p.43). Food waste scholars have thus highlighted the phenomenon of overproduction and food surplus as a potential cause of food waste. As such the food system characteristics and processes related to production, overproduction and surplus represent a promising food system sector to study how food waste is created systemically.

At this point it is useful to address some of the definitions relating to this concept of overproduction and surplus as examples of unneeded resource use. What is considered surplus food depends on how one measures the amount of food required. For instance, food surpluses are commonly considered to be food that exists more than what customers demand (Beausang et al., 2017; Garrone et al., 2014; Porter et al., 2018; Raak et al., 2017). Food surplus can also be measured in terms of the nutritional requirements of a population. Hence, food surplus has been defined in public health literature as "food energy availability beyond the requirement of the population" (Buzby and Hyman, 2012, p.561; Vandevijvere et al., 2015, p.446). Food beyond this requirement is surplus food, which facilitates both overconsumption and food waste (Friel et al., 2014; Hall et al., 2009). For the purpose of this thesis, overproduction, is more accurately described as a mode of producing that contributes to food surpluses i.e. the flow of excess food through a food chain. As such, overproduction is the "gap between production and consumption" that contributes to *unneeded* food surplus throughout a supply chain (Hic et al., 2016, p.4270; Papargyropoulou et al., 2014, p.112). Hence, it is an important aspect of this inquiry to investigate the impacts of unneeded surplus and food waste in food chains.

The mechanisms that cause systemic overproduction and food surplus persist in food chains by virtue of how food systems and food chains are designed (Mourad, 2016). In absence of any individual actors explicitly requiring or promoting overproduction, its structural nature may be pictured by invoking an *invisible hand*. Food waste scholarship has suggested various structural processes that create a reliance on overproduction leading to food surplus, and these include: the common lack of demand transparency across a complex food supply chain (Calvo-Porral et al., 2017; Halloran et al., 2014, Lemaire and Limbourg, 2019), the emphasis on specialisation and industrialisation of food commodity chains (Canali et al., 2013; Kuokkanen et al., 2017; Mourad, 2016), regulatory interventions (or the lack thereof) that have the effect of incentivising overproduction such as production-oriented subsidies (Bengtsson et al., 2019; Pritchard, 2012), routine encouragement of overconsumption (Banwell and Dixon, 2013; Friel et al., 2014) and exercises of supermarket power over suppliers (Devin and Richards, 2018; Feedback, 2018; Ghosh and Eriksson, 2019). These processes and characteristics provide useful entry points to examine and explain in-depth the concrete mechanisms and linkages between food system processes and food waste.

1.1.3 Overproduction, Surplus and Waste in Primary Horticultural Production

While overproduction and surplus can occur at any given point along the food chain (Jurgilevich et al., 2016), recent literature has drawn attention to an especially strong food surplus-waste nexus at the primary production stage with some researchers proposing that the majority of food waste is generated at the production stage (Alexander et al., 2017; Beausang et al., 2017; Cicatiello et al., 2016; Halloran et al., 2014; Johnson et al., 2018). Food surpluses generated earlier in supply chains have only intermittently been an area of concern, for instance, the economic policies that led to European Union ‘milk lakes’ and ‘butter mountains’ of the 1980s (see Bjørkhaug and Richards, 2008). Recent studies have increasingly addressed food waste in primary production, including methodologies to apprehend food waste across multiple diverse primary industries (Hartikainen et al., 2018; Redlingshöfer et al., 2017), farmers practices and challenges during the progression of a growing season (Beausang et al.,

2017), as well as pre-harvest field waste measurements and quantification (Johnson et al, 2018; Schneider et al., 2019).

A key question posed by recent research concerns the reasons why on-farm waste occurs. Some researchers relate overproduction to scenarios where food is overproduced due to specific and concrete management challenges, for instance: inaccurate demand planning (Calvo-Porral et al., 2017; Kaipia et al., 2013; Mena et al., 2011), processing and packaging errors (Garrone et al, 2014), the need to hedge against risks (Beausang et al., 2017; Lemaire and Limbourg, 2019), and sudden changes in customer demands (Raak et al., 2017; Stenmarck et al., 2011). Other research has echoed the importance of systemic supply chain impacts for farm waste, such as market context and supply chain decision processes rendering produce suboptimal for reasons of quality or economic value (Beausang et al., 2017; De Hooge et al., 2018; McKenzie et al., 2017; Porter et al., 2018). Accordingly, food waste studies recognise that both overproduction and on-farm waste may be caused by systemic and external influences beyond the control of the farmer.

Research has indicated that waste of fruit and vegetables represents a very significant share in the overall food waste globally (Buzby and Hyman, 2012; Hojgaard et al, 2013; Joensuu et al., 2020; Lebersorger and Schneider, 2014; Porter et al., 2016) as well as more specifically in Australia, due to the large volume of output as well as its perishability (Davis, 2017; McKenzie et al., 2017). For instance, Lapidge (2015, p.5) estimated horticulture contributes approximately 60% to overall economic losses due to food waste in primary production in Australia. Fruit and vegetable production has also been regarded as a major contributor to negative environmental impacts. These include impacts of resource use, e.g. land use, fresh water consumption, use of non-renewable energy and fossil fuel inputs (Friel et al., 2014; Pagotto and Halog, 2016; Principato, 2018; Rutten et al., 2013). Furthermore, the environmental impacts of horticulture have been related to significant levels of pollution emission, e.g. greenhouse gas emissions, run-offs and effluents (Bernstad et al., 2017; Parry et al., 2015; Porter et al., 2016; Vermeulen et al., 2012). While agricultural production practices have been considered a dominant contributor to food waste (Alexander et al., 2017; Porter et al., 2016), there still is a dearth of

studies on food waste in primary production (Beausang et al., 2017; Hartikainen et al., 2018; Johnson et al., 2019; Stenmark et al., 2016) as well as studies on approaches to “reduce overproduction of primary produce in order to reap the environmental benefits and the health promotion benefits of reducing food waste” (Pedersen et al. 2015, p.5).

1.1.4 The Research Gaps

By conceiving of food waste as embedded in food system activity and practices, the systemic perspective is able to position food waste as a problem of sustainable production and consumption (Capone et al., 2014; Halloran et al., 2014; Hodgins and Parizeau, 2020; O’Rourke and Lollo, 2015). As such, researchers have argued that food waste is a sustainability issue linked to food chain operations (Bengtsson et al., 2018; Redlingshöfer et al., 2020), and that changes in legislation and business behaviour towards more sustainable production and consumption are needed to reduce food waste (Parfitt et al, 2010). Others have called for food waste prevention to address and re-think “overall governance of the food system and its underlying power relationships between producers, manufacturers, retailers, food banks, NGOs, and other actors” (Mourad, 2016, p.471*).*

Consistent with this framing of food waste more broadly as an example of unsustainable production and consumption dynamics, reducing food waste has become a target under Goal 12 ‘Ensure sustainable production and Consumption’ of the Sustainable Development Goals (SDGs). To bring about more sustainable production and consumption, nation states agreed to halve food waste and loss by 2030 (Sachs et al., 2018; WRI, 2019). Furthermore, in respect of broader sustainability, food waste and its prevention have been considered as fundamentally related to a majority of the goals of sustainable development. As such, the systemic perspective proposes that improvements in sustainable development in various areas targeted by the SDG may inadvertently cause a reduction of food waste, while, conversely, food waste prevention may directly promote sustainable development by addressing and improving underlying unsustainable food system processes (FAO, 2019a, p.3).

It has been considered a core objective of food systems research, “to increase our understanding of how food system characteristics and processes influence outcomes”, including social and environmental outcomes (Ericksen, 2008, p.238). Food system research has described food system activities and characteristics in terms of producing, processing, packaging, distributing and consuming food and conceptualised their end results as outcomes of food availability, access and ultilisation (Ingram et al., 2013). From a food system perspective, many of the wide-ranging activities, processes and characteristics that contribute to food system outcomes are potentially implicated in food surplus and waste creation and present distinct areas to study existing practices and mechanisms of waste generation.

However, recent research highlighted that food waste, despite gaining increased attention as a major environmental and social challenge, has only been a marginal concern of food system studies. For example, Hodgins and Parizeau (2020, p.43) reviewed currently available research, specifically on the theoretical significance of food waste as an “intrinsic element of food systems”, and considered it marginal. Indeed, other researchers have also recognised the lack of in-depth knowledge regarding food waste as a systemic phenomenon. Halloran et al. (2014, p.295), have called for “systemic evidence” of the detailed linkages between food system design, operation and food waste as an outcome. Bengtsson et al. (2018, p.1542) have encouraged research to elaborate “what factors leave food systems prone to producing large amounts of surplus/discarded food”, while Redlingshöfer et al. (2020, p.9) suggested that future research should “focus much more on the drivers and determinants of food waste generation in all food system sectors”. Other research has highlighted the need for deeper analysis of systemic food waste (Vulcano and Ciccarese, 2017, p.46), including its “decision processes and actors” (O’Rourke and Lollo, 2015, p.242) as well as relevant “relationships and automatisms in the food chain” (Göbel et al., 2015, p.1441). Accordingly, this review identifies key research gaps in *the lack of available in-depth understanding, explanation and conceptualisation of the systemic mechanisms and linkages between production related food system activities and food waste creation, specifically in relation to overproduction and food surplus.*

Furthermore, while the system perspective contributes to an in-depth understanding of the nature and purpose of food waste prevention as well as the appropriate *system level* at which food waste prevention can be most effective, it also enables a theoretical conceptualisation of food waste as an inherent feature of food systems. This more comprehensive and systemic understanding of food waste allows for a perception of 'prevention' as a range of interventions and adaptations of food system activities, potentially leading to more sustainable practices of production and consumption. Accordingly, the second key research direction drawn from the literature review is to explain, *empirically as well as theoretically, how food waste prevention can contribute to greater sustainability of food chains and food systems*. The next section turns to a general introduction of the theoretical framework of Socio-technical Transitions to Sustainability. A more specific outline primarily of theoretical aspects pertinent to the empirical inquiry and the research questions will be provided as part of the research papers below (see section 3-5).

1.2 Theoretical Framework: Socio-technical Transitions to Sustainability

To theorise the research findings, this thesis has applied the theoretical framework of socio-technical transitions to sustainability. Sustainability transition research is founded on the premise that major environmental and social challenges derive from "patterns of unsustainable production and consumption" deeply embedded in socio-technical systems, which provide societies with large scale services such as energy, transportation and food production (Köhler et al., 2019, p.2). Consequently, addressing these major challenges requires profound transformational shifts of technology, politics, business, and culture in dominant socio-technical systems, which are termed "sustainability transitions" (Geels, 2011, p.25).

The multi-level perspective (MLP) as an influential transition research framework has conceptualised transitions as the result of interactions between regime, niche and landscape levels (Geels, 2010). A socio-technical regime refers to existing systems characterised by social and technical configurations of actors and infrastructures, norms and rules, skills and practices, that "represent the dominant way to

meet the needs of society" (Lachman, 2013, p.270). While regimes are dominant and relatively stable socio-technical configurations, niches are emerging protected spaces to incubate innovation to challenge regimes over time. The landscape level represents the wider societal backdrop and context influencing regime-niche interactions through socio-economic, demographic, cultural and ideological factors. Within a socio-technical system regimes may form specific configurations comprising heterogenous elements such as dominant industry actors, government institutions, dependent industries and co-opted consumers (Webb et al., 2017, p.408). Such configurations are able to shape their own markets to become dominant over time (Turnheim and Geels, 2012).

Regime stability and dominance are, by definition, "characterised by lock-in" (Geels, 2011, p.27), which is an established way of organising and protecting regime activities, yet also perpetuates unsustainable and suboptimal practices causing market and policy failures (Unruh, 2000, p.817). Dominant regimes invariably have a tendency to preserve stability by excluding and resisting alternative options of change (Berkhout et al., 2003, p.1508). The phenomenon of lock-in has been studied widely in relation to energy and carbon transitions (Geels, 2018; Klitkou et al., 2015; Seto et al., 2016; Unruh, 2000), but more recently also applied to the study of food systems (Ferguson, 2016; Kuokkanen et al., 2017; Meynard et al., 2018; Sala et al., 2017, Vittersø and Tangeland, 2015). Research has described a particularly powerful lock-in that occurs when private enterprise and governing institutions override market forces to form a technical-institutional complex to protect their mutual interest by reinforcing the stability of the dominant industry regime configuration (Geels, 2014; Unruh, 2000; Seto et al., 2016).

Dominant industrial regimes may be challenged by innovative and radical niche solutions, an interaction, which subsequently creates sustainable transformation. However, in cases of powerful institutional lock-in the primary concern of sustainability transitions relates to "breaking" or "escaping lock-in" (Unruh, 2002, p.317). Escaping lock-in is unlikely to be achieved from within a system configuration itself and is rather accomplished by 'exogenous events' causing extraordinary change, such as technological breakthroughs, groundbreaking regulation, or innovative scientific results (Cowan and Hulten,1996).

Besides specific exogenous events, the aspects of agency, politics and power have received attention in transition studies as an impetus for change (Köhler et al., 2019; Markard et al., 2012). In respect of power, Geels et al (2014, p.35) consider it critically important to look beyond mere regime-niche interactions and conflicts and address power relations as endogenous to dominant regime configurations and their dynamics. For example, the analysis of power relations may reveal regime resistance not as being subject to inevitable "lock-in" but as the result of "active resistance" against change. Accordingly, it is critical for all sustainability transitions and the inherent struggles of agency, power and politics, that coalitions of actors possess the "necessary wherewithal" to enforce and enact transition agendas against highly dominant and stabilised socio-technical regimes (Berkhout et al., 2003, p.1508).

By investigating regime inherent dynamics transition research has sought to understand more broadly the conditions enabling transformation of unsustainable lock-in. Describing a specific set of processes and dynamics, research has proposed the theoretical perspective of 'regime destabilisation', which describes the economic, technical, political, and cultural processes that lead to progressive weakening of regimes (Geels, 2011; Geels and Schot, 2007; Turnheim and Geels, 2012, 2013). The destabilisation trajectory is described as beginning with pressures from external environments (e.g. declining markets, eroding legitimacy), which in turn create problems for firms-in-industries (e.g. financial losses, worsening reputation, decreasing support), ultimately succeeding to undermine their commitment to the existing industry regime.

Regime destabilisation has thus been considered as a conception within the broader framework of *transition management* (Berkhout et al., 2003; Darnhofer, 2015; Köhler et al., 2019; Loorbach and Rotmans, 2010; Smith et al., 2005). It proposes that the dual processes of regime destabilisation and niche innovation are conceptually and practically interconnected. For instance, Alkemade et al. (2011, p.127) argued that the purpose and objective of transition governance cannot merely be the creation and dissemination of technical and social innovation, but also the necessary 'phasing out' of incumbent

systems, which is a vital process to facilitate opening up spaces and opportunities for creative niche development.

Once the conditions for transformation to sustainability have been achieved, transition governance has different transition approaches at its disposal (Unruh, 2002, p.318): The most commonly preferred option chosen by industry regimes is managing end of pipe products, such as carbon emissions or food waste, without changing the underlying system that caused it in the first place. The second approach seeks to protect 'continuity' and will concede only a necessary minimum of change within the boundaries of the dominant system. The third approach is rarely observed and calls for 'discontinuity' of an incumbent regime and its replacement with a new system configuration. In this context, it is crucial to consider preferences of transition governance approaches as reflective of transition *purpose and vision,* which involves broader normative contestations of the concept and objectives of sustainability itself as well as debates to determine transition pathways underpinned by diverging societal interests, values and beliefs (Geels, 2010; Savaget et al., 2019; Smith et al., 2005; Vittersø & Tangeland, 2015).

Having established the research aim as well as the theoretical frameworks informing the study, the next section presents the research questions guiding the empirical and theoretical inquiry.

1.3 Research Questions

Based on the research gaps identified from the literature review, including Paper One, an analytical conceptual review paper, as well as the literature review sections of Paper Two and Three, the research problems and directions have been defined as *providing an in-depth understanding, explanation and conceptualisation of the systemic mechanisms and linkages between food system activities and food waste creation.* On the basis of the system perspective, which regards food waste as inherent to food system processes, another more theoretical research problem aims to understand *the practical and theoretical significance of food waste for sustainable food systems and how food waste prevention, theoretically, can contribute to greater sustainability of food chains and food systems*.

In respect of the broader research program of this thesis, three research questions (RQ) provide guidance and direction for the course of the inquiry. Firstly, the starting point and initial step of this research is a review and outline of key discussions, discourses, methods and concepts in up-to-date food waste research globally. Accordingly, the research question specifying and guiding the associated tasks is posed as:

RQ1: How are issues of food waste and food waste prevention framed in key debates globally?

The literature reviews undertaken in response to this question identified existing knowledge gaps in relation to the systemic perspective of food waste creation. Specifically, key knowledge gaps are identified as the in-depth understanding of the systemic processes and mechanisms of food waste creation as well as systemic linkages between food overproduction, surplus and waste. Within the general inquiry on systemic food waste, the research problem includes a more specific focus on the phenomenon of 'overproduction', its meaning and its influence on food waste creation in primary industries. Accordingly, this thesis poses the research question to guide the empirical inquiry of systemic food waste and overproduction as follows:

RQ 2: What dominant practices and processes cause food waste at the production stage in the Australian horticulture industry? How does overproduction contribute to food waste?

Beyond the empirical inquiry on systemic food waste this research also aims to address knowledge gaps concerning broader theoretical implications of food waste and its prevention. Specifically, this thesis aims to explain and conceptualise food waste as a food system phenomenon. By doing so, it seeks to address the theoretical question of the significance of food waste prevention for sustainable food systems. Facilitating the broader theoretical inquiry, the framework of Socio-technical Transitions to Sustainability will be applied to inform the conceptual explanation of "systemic food waste creation and prevention". Socio-technical theory facilitates an explanation of the theoretical significance of food

waste within sustainable food systems as well as possible methodologies and pathways to enhance broader food system sustainability through systemic food waste prevention. Consequently, the theoretical research question is posed as follows:

RQ 3: What is the (theoretical) significance of systemic food waste prevention for transitions to sustainable food systems?

Three research papers submitted for publication constitute the primary output of the research program designed to answer the research questions, with each paper in turn addressing one specific research question. The next section presents an overview of the objectives, perspectives and relationships between the research questions and the publications of this thesis.

1.4 Research Program Linking Published Papers

This thesis has posed three research questions, each to be addressed by one research paper. All three research papers resulted directly from the ongoing research program and are part of the same empirical and theoretical inquiry. Paper One offers a review of extant food waste research and develops the concept of “Prevention Paradox”, which arises from un-systemic or even random responses, such as ad-hoc, post-hoc and end-of-pipe approaches, to a waste problem that was created systemically and inherently, i.e. through processes and mechanisms of the food system itself. The paper presents the paradoxes and conceptual dissonances of food waste prevention by examining dominant food waste narratives and highlighting how they fail to overcome the prevention paradox. Paper One concludes with a call for a systemic perspective of food waste prevention outside the realm of food waste management as well as a normative clarification of the nature and purpose of food waste prevention.

Paper Two reports on the empirical inquiry in the Australian horticulture industry. It presents research findings related to overproduction, surplus and food waste in terms of their linkage to underlying food system processes. The system phenomena supported by the empirical data and collectively described

as ‘surplus-to-waste lock-ins’ explain how surplus forms systemically through the normal functioning of locked-in food system processes, and how the processes of surplus formation do not only lead to food waste as a common result, but, over and beyond, have an effect of acceleration and amplification of food waste generation. Surplus-to-waste lock-ins thus illustrate how food waste is created systemically, transformed to waste systemically, and how food surplus and food waste may be regarded as broadly equivalent in highly concentrated and centralised industrial food supply chains. Accordingly, Paper Two emphasises the need to focus on the processes of waste creation rather than on the management of waste as an end-of-pipe product. It also proposes that tracking and disclosure of surplus, i.e. the ‘surplus footprint’, represents a vital prerequisite of genuine and effective food waste prevention.

Focusing on ways to escape ‘surplus-to-waste lock-ins’, Paper Three draws on empirical data relating to proposed food waste solutions. It shows how surplus and waste creation are inextricably tied to dominant supply chain practices and deeply engrained in the value creation process of the Australian horticulture supply chain. Drawing on socio-technical transitions theory, the paper presents a theoretical frame of ‘destabilisation’ as a transition approach to reduce and ultimately phase out unsustainable practices of production and consumption. Accordingly, the transition management agenda proposes interventions of phasing out dominant unsustainable practices, as well as commitments to creating and supporting sustainable alternatives all the way to competitive scale. In terms of transitions to sustainability, the objective is an increase in diversity of knowledge and possible pathways to sustainability, rather than their continued reduction and elimination as part of dominant regime self reinforcement and resistance to sustainable change.

The theoretical significance of food waste prevention is thus derived from a systemic understanding of food waste as inherent to locked-in food system processes. Food waste prevention, then, is understood as the adaptation and mitigation of food system processes that create waste. Paper Three thus proposes that approaches of systemic food waste prevention inherently and implicitly contribute to sustainable transitions of food systems. Equally, it proposes that initiatives targeted at improving food system sustainability in areas not specifically related to food waste, will also likely result in a reduction

of food waste as a concomitant outcome. As such, food waste prevention emerges as a pathway of transitions to sustainable food systems.

Table 3 presents an overview of the research program, the relationships between the research questions, research papers, key concepts, theoretical constructs and conclusions.

Table 3: Research programme linking the published papers

Research Question	*Paper Type / Title*	*Key Concepts*	*Theory*	*Conclusions*
RQ 1: How are the issues of food waste and food waste prevention framed in key debates globally?	***P1:*** ***Review/Discussion:*** The "Prevention Paradox": food waste prevention and the quandary of systemic surplus production (Published)	"Prevention Paradox" "Three narratives of food waste prevention" "Structural Overproduction"		1) Food waste prevention needs a normative and ontological inquiry to determine its purpose 2) Food waste prevention must overcome systemic socio-economic quandaries
RQ 2: What dominant practices and processes cause food waste at the production stage in the Australian horticulture industry? How does overproduction contribute to food waste?	***P2:*** ***Empirical/Theoretical:*** From Surplus-to-waste: A Study of Systemic Overproduction, Surplus and Food Waste in Horticultural Supply Chains (Published)	System Phenomena and Typologies: "Industry characteristics that contribute to food waste" "Industry practices that encourage surplus formation" "The failings of surplus recovery from waste"	Socio-technical Lock-In: Institutional Lock-in Cultural Lock-In Material Lock-In	1) Surplus is systemically inherent in locked-in supply chain processes 2) Surplus is an enabler and accelerator of food waste 3) Identified surplus-waste lock-ins define the transition agenda 4) Systemic food waste must be addressed holistically, i.e. along the whole supply chain

		"Surplus as an Amplifier of waste creation"		5) Surplus footprint of food chain activities determines food waste creation
RQ 3: What is the (theoretical) significance of systemic food waste prevention for transitions to sustainable food systems?	***P3: Empirical/Theoretical:*** Systemic Food Waste Prevention as a Transition Pathway to Sustainable Food Systems (Under Review)	System Phenomena and Typologies: "Competition Reduced to Price" "Quality Reduced to Appearance" "The Lack of Supply Chain Diversity" "The Uncertain Value of Surplus" "Incentives to Change"	Transitions to Sustainability: Escaping Lock-In Regime De-stabilisation Innovative Niche Support Transition Management	1) Phase out unsustainable practices and withdraw regime support 2) Niche support for diversity and supply chain innovation: Phase in alternative models and support to achieve appropriate scale 3) Identified surplus-waste lock-ins define the transition agenda: • *sustainable competition vs price competition* • *phase out unfair cosmetic standards* • *support supply chain innovation* • *prevent waste externalisation or diversion* 4) Coalitions of Interest against systemic resource waste 5) Monitor and disclose Aggregate Resource Use along the whole food chain

The following section now turns to an introduction of the qualitative research methodology designed to answer the research questions and to guide the empirical research in the Australian horticulture industry.

2. Research Design and Methodology

The design of the empirical research program suitable to answer the research questions followed the methodological framework of *Investigative Research*, which this section introduces first. Next, this chapter describes how Investigative Research shaped the methods of data sampling, collection and analysis to demonstrate how the empirical evidence was gathered and interpreted to support the research findings and conclusions.

2.1 The Investigative Research Methodology

Investigative research consists of “Social Domain Theory” (Layder, 2006, 2018), a theoretical framework of social reality, and “Adaptive Theory”, a set of practical approaches of data collection and analysis *adaptively connecting* empirical research and theory (Layder, 1998, 2006, 2018). Despite being termed ‘theory’, both components of Investigative Research are more accurately described as methodologies of social research. This section introduces these two key elements of the Investigative Research approach before proceeding to outline how they shaped the methods at every step along the research process.

2.1.1 Social Domain Theory

Social Domain Theory is the overarching framework that guides this program of empirical research. The aim of this research is the exploration and explanation of social practice and phenomena, such as overproduction, surplus and food waste creation, in terms of their “systemic” characteristics and nature. The value of Social Domain Theory lies in its combination of “agency research” with “structural research” to apprehend the systemic aspects of social phenomena (Van Gramberg, 2006, p.2), which is consistent with the aims of this inquiry. Social phenomena as described by empirical data, such as individual experiences, are interpreted in relation to underlying social domains by an analytical process of translating “social world life phenomena” into “system phenomena”. The resulting systemic

understanding of social phenomena allows explanation based on agency-structure relationships, power relationships and the transformative capacities inherent in social domains (Layder, 2018, p.28).

Social Domain Theory has evolved in the writings of Derek Layder over the past thirty years. It combines a comprehensive, inclusive model of social reality with distinctive investigative strategies to pursue two key objectives: These are, 1) to understand and explain social reality from an explicitly dualist perspective of agency and structure, which posits a universe of pre-constituted multiple and interrelated social domains, and 2) to develop practical social research methodologies related to the development of social theory from empirical data (Layder, 2006, p.272). Social Domain Theory describes four layers or domains that constitute a nuanced social reality of immediate and personal dimensions as well remote and impersonal structures (see Layder, 2006, p.274; Layder, 2018, p.11). These are set out below as an 'explanatory scheme' that enabled data analysis within this research to discern between personal and structural phenomena, as well as to understand the capacity and possibilities of actors to control and transform social practice.

The most immediate personal domain 'Psychobiography' accounts for the singular and unique personal identity and experiences of human beings, including their individual attitudes, values, dispositions and evolving psycho-social development. Psychobiography describes personal meanings, and individual social and psychological responses that ensure that the individual is "never entirely the creature of society" (Layder, 2006, p.275).

While Psychobiography as an emergent domain encompasses a person's lifetime, the domain of 'Situated Interaction' describes episodic and fleeting encounters through social interaction, which is considered the primary location to create individual and social meaning. Social Domain Theory proposes that social encounters and interactions are personal and cultural exchanges that cannot be simply reduced to a description of observed behaviour. Rather, they are shaped by individual disposition, life history, open and hidden meanings, intentions and purposes of the participants. Situated interaction also

describes the participants' ability to manage their current life situation and their power and control strategies, which are inherent in all emergent interaction.

The domain of 'Social Settings' is composed of system elements that form the immediate environment of Situated Activity, such as for example family networks, business networks, organisations, schools, hospitals, which have also been referred to as "institutional facts" (Carter and Sealey, 2000, p.10). 'Social Settings' have evolved and been shaped by "habitual actions of previous participants in social life over generations, sedimented over time and space into current practices, rules, positional powers and social and cultural expectations (Layder, 2018, p.15).

The domain of 'Contextual Resources' is the most encompassing and impersonal feature of social reality providing a socio-economic macro-context of social domains, also called 'social landscape' (Layder, 2006, p.296). 'Contextual Resources' are constituted by material resources, such as class, ethnicity, gender, religion, region and life chances as well as cultural resources, such as knowledge, beliefs, rules, customs and values, which have been historically accumulated and are "always already there" (Carter and Sealey, 2000, p.10). As such, contextual resources describe material and cultural dimensions, which are differently and unevenly allocated to individuals and groupings, and provide a fundamental and encompassing background to social life.
Figure 1 shows the layers of social domains based on a diagram provided by Layder (2006, p.273).

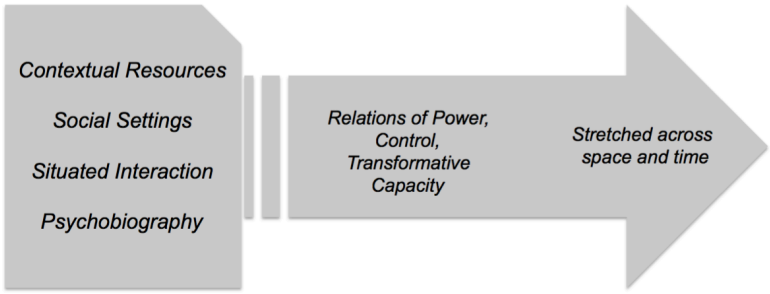

Figure 1: The theoretical framework of Social Domains

All social domains are seen as dynamic rather than static due their inherent relationships of power, which exerts a concerted influence on human behaviour and is the source of their transformative capacites. The layers of social domains unfold across time and space and constitute a multi-dimensional and diverse ontology, which underpins our structured understanding and explanation of social reality, human behaviour and social practice.

Layder (1981/2015; 2006) presented discussions of the theoretical positioning of adaptive theory and social domain theory and sought to draw their demarcation against other epistemologies, such as structural functionalism (Parson), symbolic interactionism (Mead), structuration (Giddens) and individual habitus (Bourdieu). Moreover, he also addressed the specific differences to other research methods, such as “open coding”, “thematic content analysis” and “grounded theory”. These discussions established social domain theory as a framework with a distinctly realist ontology and epistemology, with a variegated reality consisting of world/life phenomena and social domains that underpins the specific methods of social theory and practice.

As will be shown later, the efficacy of this approach lies in its ability to explain rather than merely describe social phenomena and practices. It considers social phenomena as outcomes created by underlying mechanisms within specific empirical contexts. While this approach has been regarded as a basic methodology of causal explanation in social sciences, derived from the use of *explanatory schemes* in natural sciences, such as theoretical physics and evolutionary biology, it lies outside of the empirical scientific realm to determine which specific categories, concepts and domains are ontologically justifiable to constitute “underlying mechanisms” of social reality (Cartwright, 2014, p.321; Kemp, 2005, p.172). Researchers have for instance critiqued the definition of social domains in terms of their number and scope, and proposed alternative differentiation of analytical categories. For instance, Houston (2010, p.77) objected to the combination of ideological-cultural and material-economic properties into one domain of ‘contextual resources’ and proposed a split into two categories instead.

As a more general critique, critics of *structural* approaches have also questioned the appropriateness of combining concrete empirical instances with generic frameworks and pointed to the danger of diluting the unique "sharpness" of empirical data by imposing general concepts (Pawson, 2000, p.289). To justify the use of Social Domain Theory, this thesis follows Kemp (2016, p.186) and Pawson (2000, p.292) by considering the validity of the choice of a specific explanatory scheme not in terms of its absolute metaphysical foundation, but rather in terms of its utility and preference within this research, specifically its contribution to strengthening the explanatory capacity of a specific set of empirical data. In this respect, Social Domain Theory has furnished this research with a recognised methodological framework and analytical criteria that greatly assisted in the systematic identification and justification of *a system perspective* based on the empirical data. An important facilitator in this regard was the iterative and adaptive research cycle proposed by Adaptive Theory, which will be outlined next.

2.1.2 Adaptive Theory and the Research Process

Investigative Research considers the purpose of social research to be *explanation* and *conceptualisation* rather than mere description of social reality. As such, research primarily investigates agency – structure linkages against the background of social domains (Layder, 2006, p.292; also see Carter and Sealey, 2000; Hewege and Pereira, 2013; Van Gramberg, 2006). Adaptive Theory describes the process of theory development from empirical research data and represents a set of conceptual and practical approaches to connect theory and research. Based on the adaptive research methodology, this thesis explicitly engages the empirical research with existing theory, specifically Social Domain Theory as well as the socio-technical Multi-level Perspective (see section 1.2). Adaptive research questions are composite of topical components, which seek an empirical description of observed phenomena, as well as problem components, which address agency – structure relationships by conceptually linking them to broader social domains (Layder, 2006, p.298).

The *research problem focus* is an important methodological aspect of Adaptive Theory and influences every stage of the research design. For example, data sampling is based on 'problem sampling', a

sampling strategy selecting research respondents based on their relevance to the research problem and their ability to contribute to understanding its underlying social domain linkages. Data collection protocols contain topical, problem as well as theoretical aspects related to the subject matter and interview questions need to be designed accordingly (Layder, 2018, p.93). Accordingly, the adaptive method allows conceptualisation of specific empirical behaviours, practices or phenomena as agency – structure interactions defined by linkages to social domains, thus continuously translating empirical concepts into social domain typologies. Data analysis is thus understood as "analysis with theory in mind" (Layder, 1998, p.2).

Before delving into the details of how Adaptive Theory shaped the research design, the next section addresses the broader philosophical concerns of this research by presenting the epistemological assumptions and beliefs that underpin the research methodology and methods.

2.2 Epistemologies and Evidence

This section addresses the related questions of what kind of knowledge this research is seeking and what the basic empirical and theoretical assumptions and approaches to generate this knowledge are. As a starting point this section addresses the foundational epistemological beliefs underlying this project.

2.2.1 Paradigms and Methodologies

Researchers have argued that the subject matters of social sciences fundamentally differ from natural sciences as they focus on human meaning, fluid social structures and complex non-linear and unpredictable patterns of human action shaped by historical evolutionary forces rather than obeying *natural laws* (Godfrey-Smith, 2003; Knepper, 2007; Munro, 2014). As science determines its methods and instruments based on the nature of the subject matter it studies, it follows that social research has to

determine methods “specifically suited to study human social life” (Cartwright and Montuschi, 2014; Neumann, 2014). In line with the research questions (see section 1.3), the empirical enquiry of this research is aimed at *explaining and presenting evidence* on subject matters, which may be described as 1) the complex social and economic practice of discarding large quantities of edible food, 2) the systemic and individual aspects of food waste as a social phenomenon and 3) large scale social systems that produce food waste as an outcome as well as the possibilities of systemic change to prevent it. This section addresses how the methodology adopted by this research is justified to study this specific type of subject matter and what kind of ‘evidence’ it will be able to present.

It is part of the tradition of social science research to declare the epistemological foundations that underpin and justify research designs, also termed scientific ‘paradigms’ (Kuhn, 1970). The perspective of scientific paradigms proposes that empirical evidence is not purely empirical observation but is fundamentally dependent on other diverse assumptions, beliefs and values regarding the nature of reality and the relation of the observer (Godfrey-Smith, 2003 p.48; Hall et al., 2013, p.17).

Social science researchers have applied various paradigms and theoretical frameworks well documented in the literature on social science research methods (Hall et al., 2013; MacKenzie and Knipe, 2006; Maxwell and Mittapalli, 2010; Neumann, 2014, Patton, 2002). To identify the epistemological assumptions of this thesis, three paradigms shall be introduced. The ‘positivist’ paradigm asserts the existence of a definite reality independent of the human mind that can be apprehended by impartial observation resulting in scientific knowledge that is objective, value free and universal across different contexts, places and time. The epistemological approach most commonly associated with positivism measures *regularity* of observable phenomena, quantities and relationships, which constitute a single-dimensional and *flat* ontology[1].

[1] The ontological “flatness” of positivist reality has been illustrated by references such as “only the given is real” (Schlick, 1932) and “the world only consists of surface” (Godfrey-Smith, 2003).

As a contrasting paradigm 'constructivism' or 'interpretivism' proposes a very different reality of subjective entities, events and meanings fully dependent on a process of construction by the human intellect (Neumann, 2014). Epistemologically, scientific knowledge of an intellectually constructed human reality can be obtained by *interpretation* (Hall et al., 2013, p.17). While multiple constructions and interpretations of reality are possible as they are highly context specific and may vary across culture, place and time, the underlying ontology of constructivism presents itself as uniform (Cartwright & Montuschi, 2014; Hall et al., 2013).

Due to the central importance of interpretation to obtain scientific knowledge, constructivism denies science the claim to be *value free* (Cartwright & Montuschi, 2014, p.3; also see Douglas, 2009). Rather, the interpretive paradigm specifically recognises the existence of different standpoints and lenses, which are inserted into the epistemological processes of construction and interpretation, e.g. class, gender, and race. It is therefore regarded as critically important to interpretive epistemological approaches to reflect on the position and role of the researchers, as well as the procedures of interpretation themselves (see section 2.2.3).

Situated between the single-dimensional ontologies of objectivist positivism and subjectivist constructivism, the scientific paradigm of 'experiental' or 'critical realism' advocates a pluralistic ontology constituted by both, *material objects* that exist independent of social construction and socially constructed *meanings* (Maxwell and Mittapilli, 2010, p.151; also see Bhaskar, 2016). The realist paradigm allows for diverse understandings and multiple *correct* scientific accounts of social reality. While the realist paradigm believes social reality is never fully attainable by the researcher, accounts of reality, however, are not seen as unrestricted since underlying structures of reality have an effect of *constraining* social construction of concepts, giving rise to the possibility of stable and objective knowledge (Hall et al., 2013; Maxwell and Mittapalli, 2010). In the context of this thesis, the theoretical framework of Social Domain Theory, while not explicitly claiming adherence to 'scientific realism', incorporates a number of features and properties compatible with the 'realist' paradigm of an objectivist ontology combined with a relativist epistemology. Furthermore, as will be shown below, the theoretical

framework of Socio-technical Transitions and Social Domain Theory share a degree of epistemological congruence, which makes them compatible in formulating a systems perspective (see section 2.2.2).

While researchers have widely acknowledged scientific paradigms as useful and important in drawing attention to deeper assumptions and beliefs, some also questioned their role as an *a priori* basis for determining methodology. Indeed, it has been argued that research practices and methods are not necessarily determined by single philosophical stances, and that any methodological approach may be informed by more than one paradigm (Mackenzie and Knipe, 2006; Maxwell and Mittapalli, 2010; Morgan, 2007). Accordingly, this research adopted an approach termed 'pragmatic' as it de-emphasises foundational paradigms, instead justifying methodology based on suitability to a research problem and research purpose (Mackenzie and Knipe, 2006, p.197; Morgan, 2007, p.68). Table 4 (Morgan, 2007, p.71) illustrates alternative epistemological approaches to highlight the pragmatic epistemology of this thesis and informs the further discussion of the epistemological assumptions underlying this research.

Table 4: Pragmatic alternative to key issues in social science research

	Qualitative Approach	*Quantitative Approach*	*Pragmatic Approach*
Connection of theory and data	Induction	Deduction	Abduction
Relationship to research process	Subjectivity	Objectivity	Intersubjectivity
Inference from data	Context	Generality	Transferability

The framework addresses three key aspects of scientific research. These are the relationship between theory and evidence, the epistemological stance, and the validity of conclusions drawn from the data. Placing the subject matter at the center of this research, the next section will discuss these three aspects of scientific evidence in relation to the methodologies and theoretical frameworks deployed by this research.

2.2.2 Explanation, Theory and Evidence

Subjective and Objective Features of Reality

This research has adopted the theoretical methodological framework of Social Domain Theory, a multi-layered and diverse theoretical and explanatory model of social reality inspired by a realist epistemological stance (Van Gramberg, 2006). In regards to its specific ontological assumptions Social Domain Theory considers the ontological differences between objectivism (positivism) and subjectivism (interpretivism) as a problem of emphasis on structure versus agency or interaction: "For [interpretivism], action and meaning are the central analytic concerns, for positivism, the constraints of larger social structures are the focus of enquiry" (Layder, 1981/2015, p.94). Social Domain Theory encompasses both aspects within a pluralistic and multi-layered ontology comprised of observable phenomena, entities, events as well as underlying social structures that give rise to their understanding and explanation. Correspondingly, also the "Multi-level Perspective", a conceptual approach within Socio-technical Theory, posits a multi-layered ontology consisting of landscape, regime and niche (see section 1.2). While social domains are regarded as distinct ontological entities, the layers of reality described by the Multi-level Perspective are not perceived as discrete and hierarchical, but represent heterogenous configurations that have evolved to various degrees of stability (Geels, 2011, p.36; also see Grin et al., 2010).

Social Domain Theory places human experience at a central position thus making *human meaning* a primary epistemological focus to apprehend and explain social phenomena and practice (Layder, 1981/2015, p.13; Van Gramberg, 2006, p.4). Through the ontological and epistemological framework of Social Domains, Investigative Research bridges between subjective, intersubjective and objective elements of social life and integrates them to generate explanation of social phenomena (Layder, 2018, p.28). Likewise, the epistemological core of the socio-technical Multi-level Perspective is an "interpretive" or essentially "constructivist" paradigm (Geels, 2010, p.500), which considers social reality as consisting of physical facts as well as constructed meanings. Aiming to integrate subjective and objective features

of reality into conceptual explanation, the Multi-level Perspective predominantly relies on an intrinsically historic and evolutionary approach to interpret the complex and dynamic change of a social reality that is evolving and developing through time (Geels, 2010, p.504/508; Geels, 2011, p.34; Grin et al., 2010, p.95). For the purposes of this research, exploring systemic phenomena and large scale systemic change, this means that the theoretical frameworks deployed are not only suitable to the subject matter as explanatory schemes but also epistemologically compatible, if not congruent. The relationship and symmetry between the explanatory frameworks of Social Domain Theory and Socio-technical Transitions Theory (Multi-level Perspective) are illustrated in Figure 2.

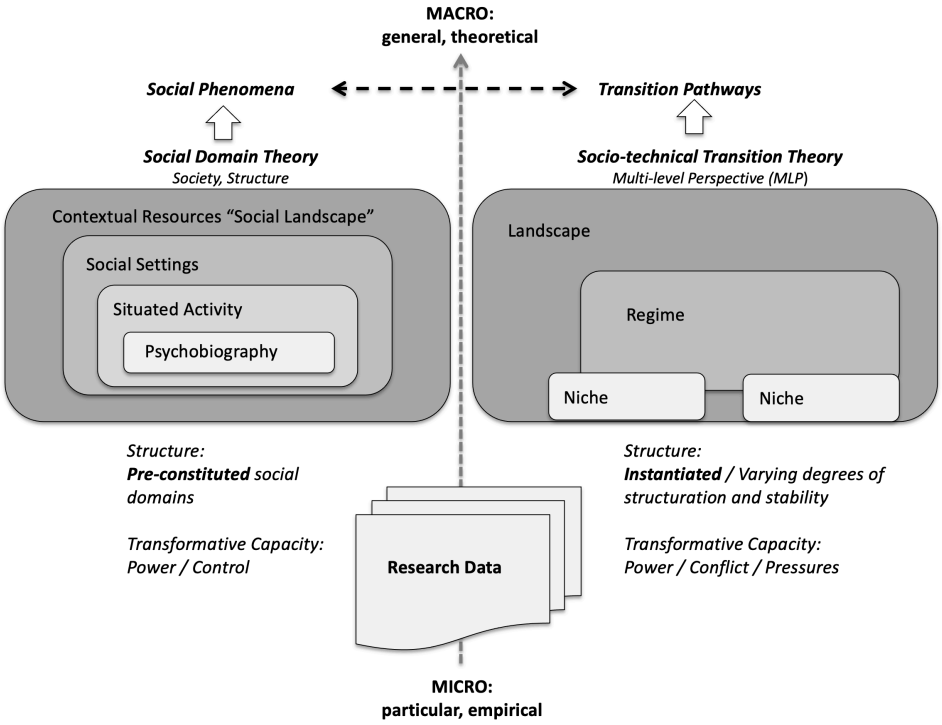

Figure 2: Epistemological Congruence between Theoretical Frameworks

In combining two theoretical frameworks this thesis makes an original contribution to Socio-technical Theory. The "Sustainability Transition Research Agenda" (Köhler et al., 2019, p.6) has highlighted the use of a "suitable alternative social research approach" as a desirable direction of further theory development. Social Domain Theory has demonstrated its usefulness within this research as an

epistemologically complementary approach to transition theory due to its capabilities to build theory from empirical and case data, connect the micro and macro levels of analysis and especially achieve *a deeper reach* into individual agency within social context through the emergent social domains of psychobiography and situated interaction.

The Importance of Theory in Empirical Research

The second key epistemological aspect concerns the importance of theory in empirical research. As outlined earlier, Adaptive Theory explicitly seeks to incorporate *extant theory* into the empirical research process. Adaptive Theory maintains that all research is influenced by theoretical assumptions, which must be addressed openly and systematically rather than implicitly and tacitly (Layder, 1998, p.5). Consequently, the use of established theory to connect existing knowledge and emerging data is an intrinsic feature of the adaptive empirical inquiry.

Similarly, the Multi-level Perspective, as a conceptual approach of Socio-technical Theory, regards the investigation of concrete empirical phenomena as its core objective, seeking to link theory to empirical research and to support theoretical concepts empirically. The Multi-level Perspective is considered a 'mid-range theory' as it emphasises a much closer relation to concrete empirical data than general or 'grand theory' (Geels, 2010). As such, the Multi-level Perspective as a framework of interpretation requires substantive empirical knowledge and theoretical sensitivity to interpret real world phenomena (Geels, 2011; Grin et al., 2010). Both theoretical frameworks applied within this research may be characterised as mid-range rather than grand theories, thus emphasizing their respective capability to generate theory from data while ensuring explanatory concepts are grounded in empirical data. As such, both approaches suit the subject matter and the objectives of this research.

Inference to Explanation

Causation as a concept has been predominantly associated with positivist research paradigms and quantitative research methods (Maxwell and Mittapalli, 2010; Neumann, 2014). Irrespective of allegiance to research paradigms, however, the explanation of reasons and causes represents an important aspect of any scientific evidence, including the evidence presented by this research. Social science research has proposed different conceptions of causal inference and explanation (Cartwright, 2014; Shenton, 2004). An important approach is 'variance theory'", or 'cause-effect explanation', which is underpinned by the positivist paradigm of regularity of observation and defines causation as probable co-variation of phenomena. Variance theory views causation as an immediate effect that can only be demonstrated by applying *control*, which refers to isolating a range of manipulations of 'independent variables' to observe and measure the degree of probability of variation of 'dependent variables' (Christensen, 1980, p.6; Neumann, 2014, p.76).

Representing a contrasting form of explanation, 'process theory' is grounded in an interpretative epistemology and proposes causal inference based on patterns, mechanisms or underlying social structures, which "produce effects systemically and in accordance with causal principles" (Munro, 2014, p.62; also see Cartwright, 2014; Godfrey-Smith, 2003; Langley, 1999; Lincoln and Guba, 1986; Maxwell and Mittapalli, 2010). Importantly for the purpose of this research, process theory is able to account for ontologically diverse social entities to support causal explanation, including meanings, physical objects and mental states, as well as to explain their structures, relationships, attributes as well as interdependent change over time. This approach has therefore also been called 'explanatory causality' as opposed to the 'descriptive causality' represented by co-variance (Shadish, 2010, p.3). Figure 3 below illustrates the differences between variance and process focused approaches to explanation. The figure is quoted from Langley (1999, p.693) and was also reproduced in Grin et al. (2010, p.93) to illustrate the epistemological foundations of socio-technical transitions theory.

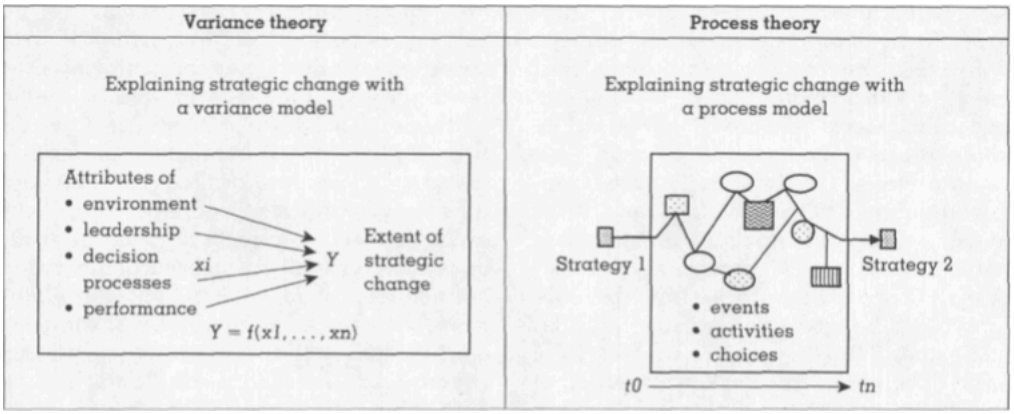

Figure 3: Process vs. variance-based explanation

Researchers, including proponents of Social Domain Theory and Socio-technical Theory have rejected probabilistic variance as the sole principle of causal explanation in social sciences by referring to certain research problems eluding variance-based cause-effect explanation. Such research problems include historic facts, events and complex long-term evolutionary developments, which are dynamic and subject to continuous change of interacting and interdependent entities and attributes. As such, they do not guarantee the availability, depth and consistency of data to achieve the type of control a variance based causal analysis requires (Grin et al., 2010; Shadish, 2010). Moreover, variance theory only permits accounts of immediate and contiguous cause-effect relationships and rejects spatially or temporally distant causation, which by definition excludes history or evolution of an entity or event as part of causal explanation.

Another type of research problem resisting variance-based approaches are events occurring within natural settings and specific multi-dimensional contexts, which need to be explained without ignoring or suppressing complexity and diversity (Lincoln and Guba, 1986; Maxwell and Mittapalli, 2010). In this regard, it has been highlighted that variance approaches in natural settings are often limited by agents which are ‘non-manipulable’ for epistemological, practical or ethical reasons and therefore have to be excluded from variance-based accounts of causation (Shadish, 2010, p.9). Moreover, variance explanation relies on isolated or controlled independent variables rather than a perception of a phenomenon as a whole. System phenomena, however, are the result of complex multi-dimensional

interactions and represent collective *emergent* dynamics and characteristics not present within the individual parts of the system. As such, 'emergent system properties' cannot be apprehended through a control based reductivist focus on individual parts or isolated factors but require apprehension of holistic context through broader explanatory schemes, such as for example evolution theory (Christakis, 2019, p.402; also see Barker and Kitcher, 2014; Godfrey-Smith, 2003; Grin et al., 2010).

The core aspects of the subject matter of this research, i.e the systemic nature of waste creation as well as long-term evolutionary transformations of large-scale waste creating systems, appear more suitably addressed by process based rather than variance-based approaches to explanation. Moreover, this research, in seeking to apprehend a specifically systemic perspective of the Australian horticulture supply chain without excluding emergent properties and relationships, considers a process-based model of explanation as better suited to the research objectives. In respect of causal explanation, the Multi-level Perspective of Socio-technical Theory emphasises "a social world that has no independent variables" (Grin et al., 2010, p.97) and maintains that simple causality is not adequate to apprehend macroscopic, long-term historic processes, which are relatively rare and involve complex emergent dynamics that require continuous sense making, interpretation and explanation (Geels, 2011, p.27). Likewise, the Investigative Research framework concurs in rejecting the sole reliance on a probabilistic cause-effect variance approach, arguing that is not justifiable to apply a "single logic of inference on a variegated multidimensional reality" (Layder, 2018, p.38). Instead, it proposes a "non-event causality based on underlying social domains" (Layder, 2018, p.42), which are contiguous and interdependent, and produce *composite causal effects* upon each other as well as on social phenomena, social practice and human behaviour (Layder, 2018, p.46/47).

Validity and Reliability of Explanatory Inference

A related aspect of scientific explanation is the wider applicability of evidence, referred to as 'external validity' in quantitative research traditions. It is considered of crucial importance to the extent that without external validity general theoretical knowledge and findings in basic research have been considered as

"nearly useless" (Neumann, 2014, p.306). The positivist paradigm regards causal explanation or scientific evidence as being unambiguous, linear and independent of context, based on regularity, stability and universality of social reality (Cartwright, 2006, p.983). Interpretivist epistemologies, however, propose that historical, cultural, institutional and personal forces deeply impact validity of explanations across different natural settings, preventing any form of generalisation of findings from a controlled experimental setting to any other alternative setting without a range of *additional assumptions* and speculative reasoning (Cartwright, 2014; Godfrey-Smith, 2003; Munro, 2014, p.63; Shadish, 2002)[2].

Renouncing external validity of evidence as the sole form of scientific knowledge, process theory regards explanation as independent of regularity and generalisation (Maxwell and Mittapalli, 2010; Piekkari and Welch, 2018). While specific explanation cannot be copy-pasted to other contexts, the sequence of reasoning leading to an explanation is *theoretically transferable* to other contexts as an 'explanatory scheme'. The Multi-level Perspective represents a process theory and may be considered such an 'explanatory scheme', which is "transferable to other contexts while maintaining its basic character and structure of analysis in different case studies and transition pathways" (Grin et al 2010, p.95). Also Social Domain Theory is not concerned with generalisation in a positivist sense, but with generating concept innovation, proposing that all "best explanations" within specific contexts will form *composite explanations*, which ultimately engender concept and theory development (Layder, 2018, p.47). Accordingly, the evidence provided by this research is a scientific account of systemic phenomena based on explanatory inference, which draws on mechanisms and specific contexts as causes that give rise to specific social phenomena and practices, such as overproduction, food surplus and food waste creation. The broader relevance of the findings of this research is supported by theoretical inference as the explanatory schemes deployed are transferable to multiple alternative natural contexts.

[2] This includes both, natural as well as controlled settings, e.g. replication studies that aim to replicate the exact setting, exact sampling, exact intervention, exact manipulation and so forth (Munro, 2014).

2.2.3 Researcher Reflexivity

Proper reflection on the position of the researcher in relation to the scientific inquiry and evidence is widely considered an important aspect of transparency and trustworthiness of scientific research (Neumann, 2014; Shenton, 2004; Suddaby, 2006). The influential positivist research tradition has been emphasising the importance of researchers to be detached, objective and their work free of personal values, which has been regarded as a distinct value position and epistemological stance in itself (Cartwright and Montuschi, 2014; Douglas, 2009; Morgan, 2010). Adaptive theory explicitly recognises that any scientific evidence may be influenced by "imported assumptions" of the researchers themselves (Layder, 1998, p.26). This thesis specifically acknowledges the certain influences of prior knowledge, assumptions and values throughout the entire research process, including the selection of the topic, the research design, the interaction and reflexivity in data collection, and the inferences and evidence drawn from the research. To ensure appropriate reflection of the researcher's position and to safeguard the scientific integrity of the study this research was mindful of suggestions regarding reflexivity from the literature on methods, primarily Layder (2018) and Shenton (2004). Accordingly, this research adhered to a recognised research methodology, preserved openness to scrutiny by the supervisory team and peers, and aimed to maintain maximum reflexive awareness of the researcher's position throughout the inquiry. A statement of personal reflections on my role as a researcher follows below.

Author Reflexivity Statement

Bias is present in all scientific research endeavours. Rather than trying to eliminate or ignore existing preconceptions, the methodology of Adaptive Theory, which guided my research, requires me to reflect on my own position and background and ensure reflexive awareness by making prior assumptions and preconceptions transparent and known. This statement is to summarise some of the reflections that have accompanied my research journey to maintain critical self-awareness and preserve the integrity of the research outcomes.

Since graduating from university almost 30 years ago I spent almost my entire work life in the fast moving consumer goods (FMCG) industry, specifically in distribution, marketing and general management. I have accumulated experience, knowledge, but also personal and professional beliefs and preconceptions of how consumer goods value chains are supposed to work, i.e. its stages, interfaces, processes, principles and actors. Working in the international FMCG industry environment I became fully adapted to and proficient in the key approaches of value creation within large-scale global supply chains, specifically the core imperative of high levels of operational and financial efficiency. At the same time, from environmental product categories and alternative supply chains I also gained first hand experience of the importance of core values, principles and purposes in shaping what participants and stakeholders might prefer to define as efficiency, profit, success or failure.

The way the demand for mass consumer goods is being fulfilled has far-reaching consequences not only for sustainable food systems but for sustainable and healthy human societies overall. Over the years, due to my specific experience, I became convinced that mass consumer good supply chains, as very substantial enterprises with deep impacts on the biosphere that supports all forms of life, must transform to ensure long-term availability and access to food and daily necessities for people across the globe. This thesis tried to identify approaches to achieve sustainable transformation based on empirical research in a mass-market supply chain setting, where my professional background could be both an asset and a liability. This statement represents a reflection on the key questions how the research process might have been shaped by my personal and professional beliefs, and how I addressed this important relationship throughout the entire inquiry.

In the following paragraphs of this statement I would like to describe three measures I adopted to ensure reflective awareness of my own personal strengths and weaknesses, beliefs and doubts, in my role as researcher. Specifically, I adhered to 1) a recognised research methodology, I established 2) a routine of regular reflection throughout the inquiry, and I preserved 3) transparency and openness to scrutiny by the supervisory team, co-authors and peers.

Adhering to a Recognised Methodology

The methodology chapter has outlined some of the epistemological and methodological assumptions underlying this research. In the context of this research, I found Adaptive Theory highly useful and succinct in terms of the theoretical as well as practical guidance provided for every step along the research process, beginning with the identification of the research problem, the research questions through to data analysis and theory building. It is a specific characteristic of Adaptive Theory to offer very practical instructions and examples for researchers to follow. As such, the adaptive research process facilitates scientific inquiry while simultaneously constraining it through its standards and requirements. For instance, Adaptive Theory demands that all concepts and explanatory relationships must be constructed on and fully supported by layers of concept indicators and empirical data. Interpretation and causal explanation must follow a specific analytical process of linking concepts to social domains, while all causal linkages must again be supported by empirical data (Layder, 2018, p.151). Strictly following and relying on a methodological discipline and a prescriptive set of instructions rather than my own intuitions and ingenuity allowed me to appreciate more reliably and objectively how the empirical data was generated, what it revealed, and what conclusions were justifiable based on empirical data rather than the researcher's, i.e. my own beliefs. While I can't claim that my personal beliefs had no influence on the evidence presented, I can confidently and certainly claim that the process how I arrived at the conclusions fully complied with a recognised research methodology.

Establishing a Routine of Reflection

In order to establish a routine of reflective observation and evaluation, I followed the advice of my PhD supervisors to keep a research journal as a record of the empirical research process. The journal began on 13 August 2018 and ended with a last entry on 26 April 2019. Furthermore, over the space of the last three years I filled about five books of handwritten research notes in chronological order, which allows me to trace the gradual development of thoughts and some of the important decisions and influences defining the research outcomes. During data analysis and formal recording of the findings as well as the

theoretical conclusions, I frequently consulted the journal as well as the notes to understand how concepts were supported and how they originated.

The journal itself consists of various observations and reflections mostly recorded within hours after the interviews, focusing on important aspects of the research. For the purpose of illustrating reflexivity, I would like to highlight three key aspects of the research progress addressed by my research notes:

Firstly, the journal recorded information related to the topic of food waste, which has been called the 'thematic' aspects of the interviews (Brinkman & Kvale, 2019). All interviews were face-to-face and mostly conducted at the respondents' place of work, an arrangement very conducive to conversations outside of the recorded interview itself. In this regard, I specifically ensured discussions or even small talk on food waste never took place before the interview, as I wanted to avoid distractions from mentioning specific aspects related to the interview topic. Interviews would generally begin with a brief introduction of the researchers and the project objectives, followed by an explanation and collection of informed consent and setting up the recording device.

Post interview discussions were frequent and on a number of occasions the respondents showed me around the premises and talked more freely about waste related issues and answered various questions. Information I received post interview was recorded in the research journal but not included in the research data, i.e. not included in the coding process. The methodology of Adaptive Theory advices that such information may be used for analytical decision-making and contextual clarification during the coding process.

Secondly, especially during the early stages, the notes also reflected on the interview process itself, including the clarity of questions, the opportunities to probe further, my overall awareness of how the 'dynamic aspects' shaped the interview outcome. The reflective notes also included my own interview technique and skills, the manner and clarity in which I posed questions, the balance between talking and listening, body language and other cues inadvertently given to respondents. In spite of the learning

gained from the pilot interview session it took some time for me to adapt to the interview protocol and its flow, including specific language and terminology used in the industry. One entry (12 October 2018) for instance served to remind myself of five key interview skills based on Denscombe (1999) simply to reinforce the mindset and prepare and improve my approach for the next interview. I considered it critical to reflect on every single interview through a brief journal entry. This reflective awareness combined with the many hours subsequently spent transcribing and listening to interview data has sharpened my understanding of how the interview process and interaction may have shaped the recorded data.

Thirdly, I used research notes also to reflect on methodological as well as theoretical issues. For instance, I recorded questions and probes for upcoming interviews or thoughts on what kind of expertise might be needed of further interviewees, which is an important aspect of adaptive 'problem sampling'. One recurring reflection concerned the 'problem focus' of social research as emphasised by Adaptive Theory. How do the interview questions and probes help to understand social domain problems, how do they help to explain social structures, practices and behaviour in line with a methodology that seeks structured explanation rather than just random narrative? The reflexive notes helped to maintain a focus on questions that address the system perspective beyond personal impressions and meanings of respondents. To illustrate this point, respondents might state, "there are no real alternatives to supermarket channels". Checking market data or specifically including questions on distribution channels in subsequent interviews represented ways to further describe and verify the true availability of distribution channels. At the same time, the inquiry followed an interpretive epistemological approach and recognised that growers may simply not perceive alternative channels as 'available to them'. From a perspective of social domains, such perceptions could exert a more profound influence on the growers' actions and decisions than public market data. Exploring both dimensions, 'share of market' as well as 'share of mind' was a critically important feature of Adaptive Theory that allowed me to focus on the research problem and on multi-dimensional data to understand and explain industry practice. In this regard, the four layers of social domains provided a useful framework to direct attention, ask questions and relate the respondents' testimony to broader system phenomena in a structured manner.

Preserving Openness and Transparency

A key feature of my PhD research journey was the interaction and collaboration with my supervisors. The thesis consists of three research papers, which they agreed to co-author with me and which has provided a great platform for continuous engagement and transparent decision-making regarding the research process and its outcomes. Due to this formal relationship of student and supervisor as well as the co-authorship we have been in continued exchange and discussion for the last three years of this research. Furthermore, we have submitted our co-authored papers to peer review and had to respond to reviewers from five different journals along the way, of which three are included in this thesis. Furthermore, I was able to present the initial concepts and findings of all three papers to peers at conferences in Adelaide, Brisbane and Christchurch. My experience of this research process was that collaboration and peer review create an environment of scientific transparency, reasoning and justification that improves the quality as well as the rigour of empirical research. This environment was very conducive to maintaining high levels of reflective awareness of my own perspectives and preconceptions.

To conclude, I believe that personal reflection and open discussion are critical features for any scientific enterprise. Through my research journey of over three years and the reliance on discipline as well as openness and transparency, I was able to experience science as a "social enterprise" with its "self-corrective mechanisms" (Douglas, 2009, p.489). Within the papers, which deal with the global mega-challenge of sustainability, the principles of transparency and diversity emerged as recurring core themes. Scoones et al. (2020, p.70) have highlighted that sustainability transitions are underpinned by the principle of "taking diverse knowledge seriously". Reflecting on my role as a researcher, I believe that I was able to contribute original knowledge because of my previous role in the industry and also despite that previous role. I am also willing to assert that this thesis offers an account of food waste prevention and sustainability in Australian horticulture that represents real features and characteristics of the Australian horticulture industry. While this original account deserves to be considered *valid and reliable*

by the standards of the discipline, I am also well aware, with full respect for the diversity of scientific knowledge, it does not represent the only possible account.

2.2.4 Conclusion

In conclusion of this section dealing with epistemology and evidence, the subject matter of this research has been characterised as the complex social practice of wasting food within the large and multidimensional social system of the Australian horticultural supply chain. The research proposes to study the subject matter in a natural setting by exploring the systemic dimensions of food waste as a social practice as well as its dynamic and emergent change over time. Based on a realist pragmatist framework, the proposed qualitative-interpretive methodology places human experience and knowledge at the core of the inquiry, and the analytical and theoretical frameworks chosen are suitable to the complex and emergent subject matters of this inquiry and are also epistemologically compatible. The scientific evidence from this research is derived through the theoretical explanatory schemes of Social Domain Theory and Socio-technical Transition Theory, both of which epistemologically rely on process-based causality and explanatory inference. Having thus established the epistemological foundation of this research, the next section will turn to a detailed outline of the qualitative methodology and the exploratory program of inquiry.

2.3 Sampling

In line with the interpretive approach, the exploratory methodology applied by this research is focused on the human experiential core within the broader social phenomena of food waste. The primary knowledge, know-how, and experience in regard to dominant industry practices of food production and waste creation rests with the institutional and individual actors in the farming, food producing and food processing industries. Accordingly, the qualitative methodology aims to explore phenomena relevant to food waste by tapping into the rich and deep understandings of fruit and vegetable supply chain actors in

Australian horticulture, who share similar and common experiences of engaging with food production and waste on a regular basis (Patton, 2002; Neumann, 2014).

To explore a subject matter of multiple individuals sharing experiences of the same phenomena, the interview method has been considered an appropriate exploratory method of data collection (Creswell and Poth, 2018). Specifically, a semi-structured interview design is well suited to the exploratory nature of the task as it allows to capture a maximum range of experiences, perceptions and knowledge through open-ended questions and permits further selective probing for more elaboration and clarification to ensure the exploratory focus remains on the research problem (Barribal and While,1994). The specific interview method deployed by this research will be described in more detail below.

To identify participants for interviews, a non-probability purposive sampling approach was undertaken. The selection of key actors within the Australian horticultural supply chains targeted a planned sample based on specific participant criteria of inclusion (Daniel, 2012, p.7; Zikmund, 2003, p.380). Following a purposive approach of 'problem sampling' as proposed by Adaptive Theory, this research selected respondents on the basis of 'problem representativeness', i.e. their likely capability to contribute to understanding the specific problem of food waste within the social context of horticulture supply chains (Layder, 2006, 2018). In line with the requirements of the problem sampling approach, purposive adaptation of data sampling, collection and analysis in response to emerging themes and concepts continuously adjusted and shaped the evolving research process.

The research respondents' depth of knowledge has been recognised as an important determinant of a 'sufficient sample size' (Bernard and Bernard, 2013). Accordingly, two implications for data sampling within this research have been considered: 1) It is essential to focus on selecting highly knowledgeable research participants rather than only aiming at a specific sample size. 2) Information collected beyond a sufficient sample size is expected to become repetitive, a phenomenon referred to as 'informational redundancy' or 'data saturation' indicating data collection is unlikely to yield new information and concepts (Sandelowski, 2003). In line with relevant literature, this research targeted a planned sample of

25-30 interviews (Bernard and Bernard, 2013, p.176; Creswell and Poth, 2018, p.104; Sim et al., 2018, p.621). For the highly diverse horticultural sector, this meant careful analysis of industry sectors along the supply chain was required to target a balanced data sample diverse enough to represent all important industry sectors, yet also deep enough to ensure adequate data depth within each sector. This targeting process is outlined in the next section.

2.3.1 Planned Sample: Objectives and Criteria

The targeting process in line with the purposive or problem sampling approach started with an initial definition of sampling criteria and objectives in terms of industry sectors, organisations and research participants (Neumann, 2014; Zikmund, 2003). Based on IBIS World Industry Reports (2020), the fruit and vegetable growing and production stage interfaces with direct supply as well as direct demand industries within the horticultural supply chain as shown in Table 5.

Table 5: Australian horticulture supply chain (Ibis World, 2020)

Supply Industries	*Growing and Production***	*Demand Industries*
A0529* Shearing, Cropping and Agricultural Support Services	A0123 Outdoor Vegetable Growing	F3605 Fruit and Vegetable Wholesaling
D2811 Water Supply	A0139 Citrus Fruit Nut & Other Fruit Growing	G4111 Supermarkets and Grocery Stores
F3319 Livestock and Other Agricultural Supplies Wholesaling	A0131 Grape Growing	C1140 Fruit and Vegetable Processing
	A0130 Apple, Pear and Stone Fruit Growing	
	A0122 Under Cover Vegetable Growing	

*Remark: *The industry codes denote Ibis World Industry reports. ** Highlighted industry sectors represent sampling targets.*

Due to their direct supply relationship to horticultural production the upstream supply industries potentially have an influence on the business practices that create food waste at the growing and production stage. Yet the targeting process needed to ensure adequate focus on the growing stage itself and has therefore not included supply industries into the planned sample. Accordingly, sampling was limited to supply chain entities directly involved in growing and production, including initial processing as an integral production activity. Initial processing refers to on-site initial processing activities like washing, sorting, grading, packing as well as more advanced initial processing such as cutting, sizing, mixing and ready-to-use packaging. Initial processing as a production activity is relevant to this research, as it potentially contributes to the creation of food waste, e.g. through grading, but also, its prevention, e.g. through further processing or reuse of surplus food. While a number of mostly large growers have initial processing capabilities, also wholesalers and agents (F3605) often operate packhouses for processing, packing, customising and consolidation. As such they have been included in the targeted sample.

Supermarkets and grocery stores (G4111) were not included in the scope of the data sampling as they are not directly involved in production. As a majority of fruit and vegetables in Australia are sold to wholesale and supermarkets (IbisWorld, 2020; Salardini, 2019; Roy Morgan, 2019), this research prioritised producers, growers and wholesalers actively engaged and interfacing with these key mass market channels, which makes them directly experienced and knowledgeable about their dominant practices and processes.

The scope of this research did not include the Fruit and Vegetable Processing Industry (C1140), which ultimately represents a food manufacturing industry subject to very different conditions and activities compared to growing and initial processing.

In sum, the horticulture production stage has been defined in terms of the six industry sectors shown in Table 6, which constitute the target population of the data sampling.

Table 6: Horticulture industry segments (Ibis World, 2020)

Industry Segment	*Description of Activities and Products*
A0123 Outdoor Vegetable Growing	Industry operators grow vegetables and pulses outdoors in open fields; Green vegetables: artichokes, asparagus, cabbages, cauliflower, broccoli, lettuce and spinach; Root vegetables: potatoes, yams, beetroot, carrots, turnips, garlic, onions and sugar beets; Fruit bearing vegetables: cucumbers, gherkins, egg plants, tomatoes and melons; Pulses: chickpeas, field peas, lupins, lentils and other legumes; Other vegetables and herbs; Vegetable seeds: fruit vegetables, leafy and green vegetables, other root vegetables, potatoes, pulses. Industry size: A$4.2 billion
A0139 Citrus Fruit Nut & Other Fruit Growing	Industry farmers grow avocados, bananas, citrus fruits, macadamia and other nuts, olives, strawberries, other fruits. Industry size: A$4 billion
A0131 Grape Growing	Industry operators primarily grow or sun-dry grapes. Grapes are grown for winemaking or to be sold as table grapes. Some of the grapes are dehydrated or dried for sale as sultanas. Grapes harvested by wineries are processed in-house rather than sold to third parties and are therefore excluded from the industry. Activities and Products: wine grapes, sun-drying grapes, table grapes, vinyard operation, wine making. Industry size: A$1.4 billion
A0130 Apple, Pear and Stone Fruit Growing	Producers in the industry grow and harvest pome fruit and stone fruit. Pome fruit contains seed chambers and an outer flesh. Stone fruit are also fleshy but have a hard stone at their core that surrounds the seed; apple, pear, quince, apricot, cherry, peach, nectarine, plum and prune; Industry size: A$ 940 million
A0122 Under Cover Vegetable Growing	Industry operators grow in greenhouses, cold frames, cloth houses and lath houses; Growing capsicum, cucumber, herbs, lettuce, mushrooms, sprouts, tomatoes, other produce;

	Industry size: A$ 748 million
F3605 Fruit and Vegetable Wholesaling	Industry businesses wholesale fresh fruit and vegetables. Produce can be brushed, washed or packaged by either producers or packaging companies. The industry excludes sales of canned or processed fruit and vegetables. Products and Activities: Citrus fruits, fruit vegetables, grapes, other fruits and nuts; other vegetables and herbs, pome and stone fruits, root vegetables. Industry size: A$ 12 billion

The overview of the industry sectors reveals horticulture as an industry with a high degree of diversity, which had to be reflected in a corresponding diversity of the sample, to gather a maximum of relevant perspectives on the subject matter. While targeting diversity, sampling was also mindful of the relative size and importance of industry sectors as high-volume crops have been associated with a larger contribution to food waste creation (Lapidge, 2015; Australian Commonwealth, 2017).

Within the industry sectors, sampling primarily targeted respondents with direct hands-on experience and knowledge of the industry, such as *growers* who are fully involved in the business and have significant financial investments at stake. Furthermore, the sampling targeted horticulture *industry and peak body representatives*, who often are experienced and knowledgeable growers themselves. Additionally, as representatives they are able to offer broader perspectives on the whole industry and across multiple sectors, including industry development, strategy, investments, and policy making. Thirdly, the target included managers or owners of *wholesale, agent and distribution companies*, and lastly, respondents from *other organisations* that interface directly with horticultural growers or processors and might be able to contribute valuable insights in areas such as waste management, food rescue or their perspective on on-farm waste more generally.

Within the targeted industry organisations, sampling criteria had to further ensure that the data collected provides ‘useful perspectives’ based on relevant, up-to-date and rich experiences and expert knowledge in the horticulture industry, which ultimately represents ‘ideal respondents’ of suitable backgrounds (Neumann, 2014). As a general rule this research aimed at interviewing either senior managers, such as

owners, directors, farm managers, chief executives, or highly specialised industry experts, in fields such as extension services, agronomy, operation, or sustainability.

2.3.2 Actual Sample Summary

The field research phase commenced on 2nd October 2018 and lasted for six months, consisting of 28 face to face interviews with 29 respondents. The total recorded interview duration was 19 hours and 31 minutes with transcripts amounting to 187,400 words. All research participants signed an informed consent form, with all offered anonymity. Two thirds of the participants agreed to be identified in subsequent research reporting, however, all participants are anonymised for consistency.

1) Industry Sectors Priority: Diversity, Size and Channels

The horticulture industry value is reported as A$11.3 billion based on the industry summary and breakdown shown in Table 7. To illustrate to what extent the criteria of diversity and priority of industry sectors were met, the table has allocated the actual sample of respondents to their respective industry sectors based on their primary field of experience and knowledge. As many respondents were directly or indirectly involved in multiple industry sectors and activities, the research allowed allocation to more than one sector, which accounts for the actual sample adding up to 65 rather than 29.

Table 7: Actual sample vs. horticulture industry segment importance (Ibis World, 2020)

Industry	*Revenue (A$ million)*	*Share*	*Act. Sample*
A0123 Outdoor Vegetable Growing	4,200	37%	15
A0139 Citrus Fruit Nut & Other Fruit Growing	4,000	36%	16
A0131 Grape Growing	1,400	12%	6
A0130 Apple, Pear and Stone Fruit Growing	940	8%	8

A0122 Under Cover Vegetable Growing	748	7%	9
F3605 Fruit and Vegetable Wholesaling	*n.a.**	*n.a.*	11
Total Horticulture Industry	11,288	100%	

*Remark: * Fruit and Vegetable Wholesaling is the largest segment with about A$12 billion revenue, which largely represents the resale value of the primary industry revenues reported. To avoid double counting or detailed reconciliation of revenues, the wholesale segment revenue has not been indicated.*

As the Australian horticulture industry is highly concentrated in terms of its mass-market distribution, the sampling aimed to capture growers and producers who supply the most important market channels, i.e. the major supermarkets and wholesalers. Out of the 29 interviews, 13 respondents were engaged in supplying supermarkets, 10 respondents were mainly selling to wholesale, agents and central markets, and 15 respondents indicated other channels, including export. Also in this case some multiple allocations were permitted. This summary highlights how the actual sample recruited met the objectives of the planned sample both in terms of diversity, as well as priority of sector size and mass-market distribution channels.

2) Industry Organisations and Research Participants

In accordance with the sampling objectives the actual sample covered four categories of industry organisations. Table 8 indicates an actual sample of ‘processors’, which, however, always were either ‘growers’ or ‘wholesalers’, who have initial processing capability and relevant infrastructure. Some participants have been allocated twice as they represented multiple categories, e.g. grower and industry representative or grower and processor. As part of the sampling target, two interviews were conducted with agricultural waste management experts and one with a food rescue organisation.

Table 8: Summary of horticulture industry organisations surveyed

Horticulture Industry Organisations	*Actual Sample*
Growers	16
Industry Bodies *	12
Processors (either Growers or Wholesale) **	7
Wholesale / Agent / Distributor ***	7
Other Industry Services	3

Remarks: * Seven Industry Representatives were also Growers; ** Seven Processors were either Growers or Agents; *** Three Agents were also Growers.

The actual sample of respondents consisted of owners of growing operations, high-level management, industry representatives and senior technical experts in horticulture. The summary of respondents presented in Table 9 has been de-identified as they could become easily identifiable due to their positions within the industry sector and/or organisation.

Table 9: Summary of research participants

Ref.	***Position***	***Organisation***	***Industry***	***Length (mins.)***	***Location***
01	Technical Manager	Industry Association	FRUIT	39:00	Brisbane
02a	Owner*	Grower	VEG	55:00	South East Queensland
02b	Owner*	Grower	VEG	55:00	South East Queensland
03	Managing Director	Grower / Wholesale / Agent / Distributor	WHS/FRUIT	30:47	Brisbane
04	Managing Director	Wholesale / Agent / Distributor	WHS/FRUIT	49:04	Brisbane
05	Owner / Industry Representative	Grower / Industry Association	FRUIT	47:48	South East Queensland
06	Owner / CEO	Grower / Industry Association	FRUIT	47:47	Brisbane
07	Owner / Executive Officer	Grower / Industry Association	FRUIT	56:48	South East Queensland

08	Business Manager	Grower / Wholesale / Agent / Distributor	VEG	56:13	South East Queensland
09	Owner / Industry Representative	Grower / Peak Industry Body	VEG	*55:00*	South East Queensland
10	Technical Director	Grower	FRUIT	38:47	South East Queensland
11	Technical Manager	Peak Industry Body	FRUIT/VEG	39:30	Melbourne
12	Director	Wholesale / Agent / Distributor	WHS	40:59	Melbourne
13	Technical Manager	Industry Association	FRUIT	37:49	Melbourne
14	Industry Manager	Peak Industry Body	FRUIT/VEG	39:16	Melbourne
15	Owner	Grower	VEG	38:16	South East Victoria
16	Director	Grower	VEG	46:40	South East Queensland
17	Technical Manager	Peak Industry Body	FRUIT/VEG	40:26	South East Queensland
18	Food Supply Manager	Other Industry Services	OTHER	20:35	Brisbane
19	Owner / Industry Representative	Grower / Peak Industry Body	VEG	41:04	South East Queensland
20	General Manager	Other Industry Services	OTHER	44:31	South East Queensland
21	Production Manager	Grower	VEG	37:31	South East Victoria
22	Owner	Wholesale / Agent / Distributor	WHS	34:32	Melbourne
23	Senior Officer	Peak Industry Body	FRUIT/VEG	39:11	Brisbane
24	Owner / CEO	Grower / Industry Association	FRUIT	38:01	Northern Rivers
25	Director	Wholesale / Agent / Distributor	WHS	42:24	Brisbane
26	Managing Director	Grower	VEG	32:23	South East Queensland
27	Owner / Director	Grower / Wholesale / Agent / Distributor	FRUIT	44:50	South East Queensland
28	Director	Other Industry Services	OTHER	37:31	South East Queensland

* Interview session 2 combined two growers in one session.

The summary table of interview participants shows that the research participants were considered qualified and familiar with the industry. They were engaged and active in significant commodity sectors as well as highly relevant organisations and positions.

2.4 Data Collection

Having defined sampling objectives and sampling criteria, this chapter turns to an outline of the data collection protocol, including considerations concerning the application for human research ethics approval, the design of the interview questionnaire, as well as the actual arrangements of face-to-face interviews.

2.4.1 Human Research Ethics

The University Human Research Ethics Committee approved the research proposal in August 2018 (QUT Ethics Approval Number 1800000744). The application was considered *negligible or low risk* in accordance with chapter 2.1 of the Australian National Statement, as the research target involves competent and consenting adults currently employed or otherwise engaged in work within the food industry. The evaluation anticipated no foreseeable risks beyond inconvenience.

In line with relevant guidelines, all research participants received a ‘research information folder’, an ‘informed consent form’ and an ‘invitation for research participation’, outlining the purpose as well as the procedures of the research. The researcher addressed all questions concerning the research procedures personally and contact details of the research supervisors as well as the QUT Research Ethics Committee were provided to interviewees. Moreover, research participants were required to sign an informed consent form to formally accept the terms of participation and to certify their authority to speak on behalf of their organisation, including their consent to audio recording and further use of the interview data for research purposes. Research participation was confidential unless respondents chose to indicate their willingness to be named in the study.

2.4.2 Interview Protocol

At the core of the interview protocol are the interview questions as the primary instrument to elicit responses, reactions and information from research respondents. The design of interview questions and the preparations for the face-to-face interviews have been guided by a number of considerations to ensure data collection is able to receive insightful data relevant to the research objectives.

In regard to the design of interview questions, Brinkmann and Kvale (2019) stress the importance of keeping interview questions clearly related to the research problem, which is widely emphasized in the literature on methods and was also a primary concern of this research (Bariball and While,1994; Creswell, 2007). Semi-structured interview approaches commonly rely on open-ended questions, which facilitate an exploratory process of uncovering relevant experiences, insights and knowledge in interaction with the participants. The lack of pre-set structure, however, can cause the interview to digress from the research problem. A common approach to balancing the exploratory objectives of the interview with a focus on the research problem relies on the use of follow-up questions and probes, which is the approach also taken by this research.

Interview questions have a *thematic* focus, which is the task of producing and evoking information relevant to the research, but also important *dynamic* aspects, which shape the interaction during the interview process (Brinkmann and Kvale, 2019, p.7; also see Creswell, 2007). The language used throughout the interviews may determine the type of interaction between researcher and participant, which may lead to different interview results. Bariball and While (1994, p.333) suggest in this regard that all aspects of interview protocols should be primarily attentive to the specific situation and needs of the *respondent*, which incudes appropriate length of the interview, and a comfortable and undisturbed setting. In line with recommended good research practice for the semi-structured interview method (Jacob and Furgerson, 2012) the interview questionnaire was tested in a pilot interview session prior to commencement of data collection. The main objective of the pilot interview was to ensure that the interview questions were clear, evocative and pertinent, while the interview flow was logical and consistent.

The initial interview protocol consisted of six questions and various probes designed for an in-depth exploration of the research questions. One important consideration was to ensure the interview protocol was well aligned with the research questions guiding the empirical inquiry, specifically *RQ 2: What dominant practices and processes cause food waste at the production stage in the Australian horticulture industry? How does overproduction contribute to food waste?* and *RQ 3: What is the (theoretical) significance of food waste prevention for transitions to sustainable food systems?*

An important requirement, based on the adaptive theory methodology, was for interview questions not only to address the topical or thematic aspect of the subject matter under research, but also the "problem" dimensions of the research questions, which explore phenomena in terms of their linkages to structure agency-problems and social domains. Interview questions and probes thus had to be designed to elicit responses explaining life world as well as system phenomena (Layder, 2018, p.100), which required continuous adaptation of interview questions and probes to ensure their relevance for explanation of topical as well as a problem aspects.

The flow of the interview questionnaire is critical for the dynamics of the interview situation. The design of the questionnaire intended a relaxing and comfortable lead-in with introductory questions on the interviewee's organisation, background and specific role and challenges (Q1). With the interview process settled in, the questions then turned to addressing more specific food waste causes (Q2) and food waste management practices and solutions (Q3). The intention was to establish an understanding of food waste in the context of horticulture, before moving on to the topics of overproduction and surplus (Q4) and surplus management (Q5). The questionnaire closed by exploring food waste and overproduction in relation to long term sustainability of the industry and by eliciting thoughts and ideas on the future sustainability of horticulture (Q6). The research papers included in this thesis predominantly relied on findings from Q1- Q5. Data from Q6 will be used for a further publication that was not yet completed in time for the completion of this thesis. Table 10 below presents interview questions and various follow-up

questions after some adaptations during the early data collection period and also indicates their links to the research problem and social domains.

Table 10: Interview protocol (November 2018)

Interview Questions: 23rd November 2018	*Links to Research Topic and Problem*
Q1: What is your role in your business/organisation? What are your company's key activities in the food industry? Can you tell me about your sales channels? What are the key priorities in your business right now? What are the long-term goals/visions of your business? What do you consider success/achievement in your business?	Topical: Industry background, food chain Research Question: 2 & 3 Problem/Domain: psychobiography, setting, situation
Q2: What do you consider food waste in your business? What does your company/industry consider food waste or loss? Why is there waste/loss in your company/industry? Is food waste / loss considered a problem in your company and industry? Why / by whom?	Topical: food waste definition, causes, practices, meaning Research Question 2 Problem/Domain: situated activity, setting, context
Q3: What kind of 'food waste management' practices do companies in your industry follow? Do companies in your industry collect data about loss/waste? What kind of data / Why? Do companies have designated personnel dealing with waste / loss? Is there any R&D about waste/loss and sustainability in your industry? What/Why? Can you tell me how companies commonly dispose of waste?	Topical: food waste prevention - definition, causes, practices, meaning Research Question 2 Problem/Domain: situated activity, setting
Q4: Is there overproduction / oversupply / surplus production in the industry? How do you know there is oversupply? What happens during glut cycles in your business and the industry? Can you tell me about waste/loss during times of oversupply/glut or undersupply/shortage? Why? Is there long-term permanent oversupply in the industry? Why? How does the industry manage oversupply? Is the industry producing more than the market needs? Why?	Topical: overproduction and surplus - definition, causes, practices, meaning Research Question 2 and 3 Problem/Domain: situated activity, setting, context

Q5: How can surplus be avoided? How do growers decide how much to produce? Do producers engage in demand planning? How do they do it? What/why? Can better data and shared data solve the oversupply problem? How? What can be done to prevent oversupply? How/Who? How do you manage surplus produce?	Topical: prevention and management of overproduction and surplus - solutions, practices, meaning Research Question 2 and 3 Problem: situated activity, setting, context
Q6: How to does waste/loss impact resource management? Do you consider current practices of resource use sustainable in the long term? Why / How? What will the industry look like in 10-20-30 years? Will you produce more or less than now? Will food cost more or less? Why? What should be done about waste until 2030?	Topical: food waste, overproduction and Sustainability; long-term outlook, personal and professional perspective Research Question 3 Problem/Domain: psychobiography, setting, context

As described above, it is a fundamental characteristic of Adaptive Theory to promote an iterative adaptive interplay between emerging data, data analysis and further data sampling and collection. Accordingly, during the earlier stages of the research interviews adaptive adjustments were necessary on the basis of emerging data. Moreover, ongoing reflections on my role, position and performance as a researcher motivated adjustments, which have been recorded in the research journal (see Researcher Reflexivity Statement, 2.2.3). While the interview questions remained comparatively stable after an initial phase of data collection, the probes and follow-up questions became increasingly focused and 'problem relevant' to explore and confirm specific influences, interactions, settings and contexts in addition to personal experiences.

2.4.3 Data Collection Implementation

Data collection started in October 2018 and required about seven months until completion of field trips in April 2019. The researcher initially conducted searches online as well as through industry associations to identify suitable respondents. Initial contact was made by phone, followed by emails containing the research information package before confirming participation and appointments for a face-to-face interview. The researcher did not offer any gratuities, allowances or reimbursements to participants. Out of seventy initial contacts twenty-nine respondents participated in the research, which represents a participation rate of 41%.

The researcher conducted all interviews without exception face-to-face, interviews lasted for an average of just under 42 minutes and took place at the participants' offices. The researcher recorded interviews using an audio recording device and uploaded data on the same day to the online transcription service 'trint'. The adherence to a strict face-to-face interview format entailed a significant amount of travelling predominantly in the growing regions around the research home base of Brisbane, including Lockyer Valley, Scenic Rim, Southern Downs, Sunshine Coast, and in and around Melbourne, including Cardinia and Koo Wee Rup. The face-to-face approach provided increased opportunity for interaction and sometimes more casual exchanges with the respondents, who in a number of cases provided a tour of their operation and additional information, which was recorded in the field research notes and research diary.

In line with the adaptive theory approach, data analysis supported by Nvivo 12 started in November 2019 and was conducted in parallel to data collection to enable iterative adaptive responses and adjustments. In May 2019 the researchers sent a feed-back report on the interview responses to all research participants, followed by a second report in September 2019, which informed participants of the results of the research findings and formally completed the data collection process.

2.5 Data Analysis

The iterative and adaptive process of data analysis proposed by Adaptive Theory and applied within this research is illustrated in Figure 2:

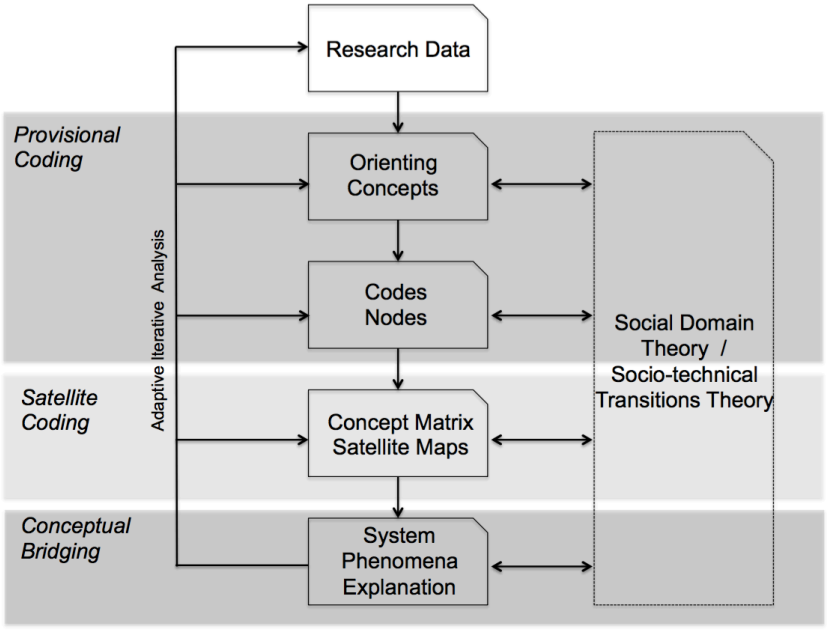

Figure 4: Adaptive data analysis "with theory in mind"

Broadly, data analysis consisted of three stages, 'provisional coding', 'satellite coding' and 'conceptual bridging and explanation'. This section describes the detailed activities and objectives at each stage, which combined to generate the research findings.

2.5.1 Provisional Coding

Provisional coding is the initial stage of analysis in Adaptive Theory (Layder, 1998, p.2). In the specific case of this project, the researcher selected a number of codes as 'orienting concepts', based on literature and theory review, to guide the initial empirical inquiry. As such, provisional codes initially

appear as ‘researcher defined codes’ and, as the inquiry evolves, ‘research participant defined codes’ (Layder, 2018, p.83). This approach of confronting extant ideas with the emerging raw empirical data (Layder, 2018, p.104) was able to generate a mix of descriptive and conceptual codes and allowed the researcher to explore a wider range of *explanatory possibilities*. This research followed the practical guidance of Adaptive Theory, which calls for at least two to three iterative cycles of analysis and adaptive responses in data collection to maintain exploratory, explanatory and theoretical openness throughout the coding process, while all along preserving close connection to empirical data. The researcher was mindful of the danger of limiting the investigation by focusing too early and too deep on categorisation or conceptualisation beyond ‘provisional coding’, as such premature decisions and determinations may prevent relevant emerging concepts from coming to the fore (Layder, 1998).

During the provisional coding stage of this research, data nodes and concepts were still very tentatively defined and required further empirical exploration to evoke clearer and more definite meanings. For example, the emerging concepts of ‘surplus formation’ and their relationship to waste creation called for a number of possible *adaptive responses* in data collection in order to deepen their exploration as emerging concepts. Adaptive responses would typically begin with analytical questions regarding emerging concepts and available empirical data. Table 11 lists examples of analytical questions that were used to identify potential adaptive responses during provisional coding:

Table 11: Data analysis and adaptive responses

Analytical Aspect	Area of Focus
Data Sampling	Who is likely to understand overproduction of surplus? Who is primarily knowledgeable about the overproduction and the management/disposal of surplus?
Data Collection	What causes surplus and oversupply? How does overproduction contribute to surplus? Does reduced demand result in reduced production? Why do growers overproduce if it causes economic losses and resource waste?
Situated Activity	How do growers decide to overproduce? What interaction

	causes overproduction to happen? Who is in control of the situation?
Social Setting	What practices in the industry or supply chain encourage overproduction? How did the practice become established? Who controls the practices, who can change it and who benefits?
Theoretical	Is overproduction a common feature of the prevailing dominant industry regime? What alternative production practices within the industry do we know of? What is a regime in horticulture? What is a niche? How do regime/niche interactions shape future sustainability of horticulture?

Recording analytical questions is part of the methodological reflection by the researcher, which was instrumental in guiding the ongoing data sampling, adjust the focus or the nuances of interview questions and to ensure that data collection and analysis were sensitive and receptive to concepts emerging from the ongoing exploration.

Emerging concepts are a form of what Layder (2018, p.102) has called “nascent explanation” of empirical data. The approach chosen for this research acknowledged the implied provisional nature of emerging concepts and recognised, that emerging concepts continuously present new questions and knowledge gaps that need to be addressed and explored further. In this regard the adaptive iterative methodology of provisional data analysis was very useful in guiding the ongoing inquiry and allowing concepts to mature as the data collection advanced.

2.5.2 Satellite Coding and the Concept Indicator Matrix

As the range of codes, nodes and concepts became more clearly defined, the analytical focus of data analysis turned to arranging thematic codes and ‘nodes’[3] into broader concepts that progressively increased in explanatory scope and power while maintaining strong linkages to the emerging empirical data. Adaptive Theory has descriptively named this process ‘satellite coding’ or ‘core coding’ (Layder,

[3] “Node” is a term used in Nvivo for clusters of related codes.

1998) as the emerging concepts are visualised as the centre of an arrangement of pertinent nodes and codes.

The main focus and challenge at the satellite coding stage was to generate concepts from vast amounts of data. The coding approach taken initially allowed for multiple allocations of codes to child-nodes and nodes in order to prevent premature coding decisions from limiting the full development of emerging concepts. The analytical process of satellite coding progressively and iteratively elaborated the multi-layered architecture supporting the full meaning of concepts while reducing allocations through analytical decision-making. The multiple layers of aggregation of codes initially increased the number of references in the Nvivo codebook to 8,465. After analytical streamlining of concepts and codes the process of analysis and concept generation settled on 3,122 primary data references directly connected to empirical data as 'concept indicators', which fulfilled a key requirement of Adaptive Theory. The concept indicators enabled the researcher to compile satellite concept maps, which capture and delineate the multiple dimensions, layers and meanings of emerging concepts, and, through their joining with other concept maps, to "construct interconnected webs of concepts to support robust explanation" (Layder, 2018, p.105).

To give a concrete illustration of the analytical and interpretive process that established connections of vast amounts of data references to distinct networks of meaning, the concept of 'surplus-to-waste mechanics' shall serve as an example. In total, fourteen concepts emerged from the analysis and initial interpretation of data and were supported by satellite concept maps of varying complexity and depth. Table 12 represents an overview of the concepts generated at the satellite coding stage, with 'surplus-to-waste mechanics' highlighted as the example used to illustrate the unfolding analytical process.

Table 12: Concept Maps and Social Phenomena

Satellite Concept Maps:
1) Social Domain Linkages
2) “The Grower boxed in a Corner”
3) The Marketplace
4) Government Support
5) Consumer (Dis)connect
6) Supermarket Power and Efficiency
7) Surplus-to-waste Mechanics
8) Waste: Causes and Reasons
9) Waste Priority
10) Waste Chains
11) Surplus/Waste Solutions
12) Value-adding
13) Export
14) Sustainable Horticulture

In line with the analytical method of Adaptive Theory, each of the fourteen concepts was represented and supported by a satellite map that captured the underlying architecture of nodes, child-nodes and codes. Figure 3 shows the satellite map for the concept ‘surplus-to-waste mechanics’, which represents the conceptual centerpiece of the research findings on ‘surplus-to-waste lock-In’ presented in Paper Two. The rectangular highlight indicates the concept of ‘surplus formation’ as one of three key conceptual pillars of surplus-to-waste mechanics.

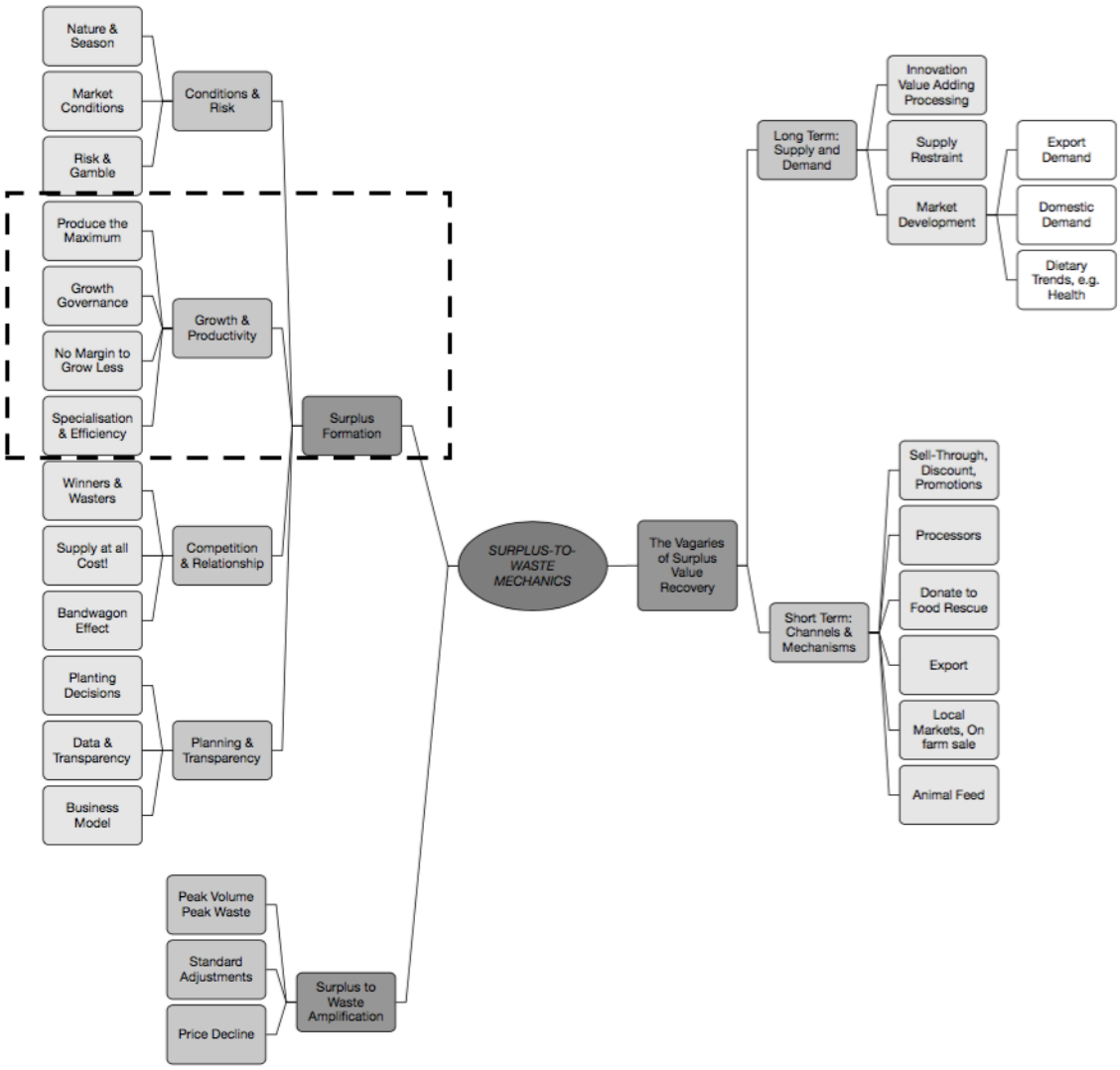

Figure 5: Satellite concept map "Surplus-to-waste Mechanics"

'Surplus formation' in Figure 3 (rectangular highlight), as a sub-concept of surplus-to-waste mechanics, describes and unpacks a less provisional and more definite range of practices, processes and characteristics of the food supply chain and the ways they result in surplus. As such 'surplus formation' epitomises and conceptualises empirical evidence of practices and arrangements within the supply chain that cause *surplus to form exigently* due to their specific design and operational characteristics. Besides revealing the complex nature of surplus creation in food chains the satellite coding method was also useful to apprehend, delineate and conceptualise key phenomena, such as 'overproduction'.

As shown in Figure 3, four separate nodes represent the different layers of the meaning and definition of 'surplus formation', these are 'conditions & risk', 'growth & productivity', 'competition & relationships' and 'planning & transparency'. To uncover the conceptual foundations of 'surplus formation' in greater depth, Table 13 presents a 'concept indicator matrix', which illustrates the supporting architecture of concepts, nodes, child-nodes and thematic codes that combine to define the concept of 'surplus formation' and its linkage to empirical data. Of the four nodes, Table 12 displays only the node of 'growth and productivity' as an example of thematic codes providing the empirical basis *indicating* and empirically supporting the concept of surplus formation.

Table 13: Surplus formation: Concept indicators for "Growth & Productivity"

PHENOMENON	***Surplus-to-waste Mechanics***			
CONCEPTS	***Surplus Formation***	*Failings of Surplus Recovery*	*Surplus-to-Waste Amplification*	
NODES	***Growth & Productivity***	*Conditions and Risk*	*Competition & Relationship*	*Planning & Transparency*
CHILD NODES	***Produce the Maximum!***	***Growth Governance***	***No Margin to Grow Less!***	***Specialization & Efficiency***
CODES (*selected*)	I don't think anyone would like to reduce their production. I think everyone is out there to increase their production, Well we're hoping to produce more! (07)	That's really interesting about the fact that on one hand we've got they oversupply and then the other hand we've got to double food production, I don't know how to mill those two things together in Australia (01)	Well they can't tell the bank manager that they're going to have a lower yield for the next three years. Because they are borderline at the moment anyway. You know they've not got money to spare. They can't, there's no margin for growing less (02)	They've gone from growing maybe 20 things over the course of a year to now focusing on maybe 3 things. And that means that they've got huge amounts of produce that they have to get rid of instead of having that diversity, which is a huge risk (25)

	And I need to maximize my yield. That's the key to profitability is maximizing productivity. So that's all I focus on. (06)	Our consumption per capita is decreasing, so the volume if anything should be going down, but we generally tend to be going up in production (13)	They've got to keep money going through their bank accounts. Something is better than nothing. But that's where waste starts at that end (04)	So to warrant that investment you need a big throughput, but then you're stuck with the problems of monoculture, you know, diseases, pest (15)
	Well you produce your maximum, I think. (05)	Governments say: We need 40 percent more product. Well, if Woolies and Coles, Aldi etc actually reviewed their product spec, that 40 percent is sitting there, on farm now, that could come through. You wouldn't have to grow anymore. It's already there (17)	They can't give up, because, "How do I pay for that debt?" Yes, so you have to keep going and hoping for the best (25)	No because we're getting better each year, we're getting more efficient. The problem is that all the farmers are getting better at what they do, which means that they're not producing what they were ten years ago. They're producing more. So therefore it contributes to oversupply because our population is not growing that quickly (14)

The selection of concept indicators that support the child-nodes has been limited to only three indicators per child-node for the purpose of clarity in illustrating the methodological process and the concept architecture. Based on the codebook generated through data analysis, the child nodes generally consisted of about eight to fifteen thematic codes, which a shows the significant depth of empirical data underpinning key concepts.

By using ‘surplus-to-waste mechanics’ as an example, Tables 12 and 13 as well as Figure 3 present in detail how the analytical step of satellite coding was able to construct fourteen satellite concept maps that emerged from and remained closely linked to the empirical data. Subsequently, data analysis was

able to link and merge the satellite maps into interconnected webs of explanation of the social phenomena of surplus production and waste creation.

2.5.3 Conceptual Bridging and Explanation

Before the empirical evidence of social phenomena can be finally considered as explanation, the satellite concept maps themselves need to undergo a final stage of conceptual analysis to justify the conclusions and inferences drawn from a particular configuration of concepts and codes. Following the methodology of Adaptive Theory, this final stage of explanation and conceptualization focuses data analysis on the explanatory possibilities presented by the linkages of concepts to *structure-agency relationships* against their *background of social domains*.

Social Domain Theory provides a methodological practical approach to analyse satellite concepts in relation to *agency and structure*, as the four social domains are layered according to their specific transformative capacity to change over time. Social Domains range from the emergent (agency) domains ‘psychobiography’ and ‘situated interaction’ to the contextual (structure) domains of ‘social settings’ and ‘contextual resources’. In terms of the analytical process itself, the researcher evaluated and interpreted how social phenomena and emerging concepts relate to social domains and their transformative capacity, i.e. the capacity to transform or being transformed. As such, the codes and concepts were interpreted as a mix of behavioural (acting) and systemic (constraining) elements. Adaptive Theory refers to this process of conceptual translation of life world phenomena into social domain or system phenomena, as “conceptual bridging” (Layder, 2018, p.85).

Aiming to bridge agency and system aspects of emerging concepts with Social Domains, data analysis within this research explored evidence of power relations, i.e. the capacity for control or the capacity to transform social practice (Layder, 2006). In the words of Layder (2018, p.65), power relations “that run through each domain should be considered as possible explanatory factors, especially when they

combine in particular empirical circumstances". Power as an analytical instrument is thus conceived of as not generic, abstract and uniform but highly specific to particular aspects and contexts of the social world. Data analysis within this research focused on the capacity of control in each domain to understand the multitude of transformative influences that combined in particular empirical situations to produce social outcomes described by research participants during interviews. As an 'explanatory scheme' of social transformation, adaptive analysis was thus able to arrive at concrete propositions about the extent to which interpersonal control was able to shape social practice in relation to surplus and waste creation (Layder, 2006). To keep with the chosen example, 'surplus formation' initially emerged as a provisional concept and evolved through the subsequent analytical process of satellite coding into a broader conceptualisation of research findings on 'prevailing practices contributing to or causing surplus formation'. The final analytical and *interpretive* step of conceptual bridging reveals the nature of processes and characteristics that underpin 'surplus formation' as structural, or systemic, rather than behavioural or deliberate, allowing the researcher to classify the concept of 'surplus formation' as *systemic*.

To demonstrate the practical process of interpretation undertaken to generate the research findings in more detail, Table 14, which is based on Layder (2018, p.11), highlights a number of analytical perspectives the researcher considered during the interpretive stage of concept bridging:

Table 14: Analytical questions for social domain bridging

Social Domain / Analytical Focus
Psychobiography
Personal identity, emotions, motives, style; aspirations and motivations over time;
Response to authority, power, control in situations and settings; subjective changes in psychobiography due to settings/context;
Personal capacity to deal with social circumstances; coping and resilience; fulfillment, commitment, entrapment;

Situated Activity
Routine and significant encounters and interactions;
Quality, purpose and effects of social interactions;
Situational power to negotiate and change social world; capacity to control a situation;
Social Settings
Established character of different types of settings; attachment or commitment to social setting; personal experience of settings;
Formal positions of authority and expertise; principles of organisation; the individual's role in organisations;
Organisational history of settings to become organised in their present shape; habitual practices of previous participants that formed social settings;
Contextual Resources
Historical emergence of culture, values, rules and norms; current social attitudes and behaviour;
dominant power of any group; prevaling discrimination of any group; equal distribution of social, cultural and economic resources;
Political and economic institutions, ideologies and values;

Different analytical questions as shown in Table 14 can be asked of the data in order to bridge the concepts with underlying social domains and evaluate their inherent capacity to control or transform social reality. This process is intrinsically *qualitative and interpretive*, and it is of critical importance to support the conclusions of the interpretive process by empirical data and concept indicators. In the case of 'surplus formation' the bridging of concepts revealed a strong emphasis on the contextual domains and very limited transformative capacity by individual growers and producers, which revealed the nature of surplus formation as a phenomenon of systemic constraint rather than individual behavioural choice. For example, situated social interactions described by research participants were of empirical explanatory significance as they revealed the power differential in the supply chain: Research participants described the meetings with the supermarket buyer ("make a loss just to maintain the relationship"), the bank manager ("they can't tell the bank manager they are going to have lower yield"), the industry and government representatives ("consumption per capita is decreasing but we generally

tend to go up in production"; "we need to grow output volume by forty percent"), agricultural supply companies ("to warrant that investment you need a big throughput, but then you're stuck with the problems of monoculture") are illustrative of social context and settings that systemically shape and direct industry practices in horticulture, specifically, in this case, emphasising further growth of production output. The common response by growers, who lacked the wherewithal to control the situation or transform established practices, was "to simply produce the maximum they can".

2.6 Conclusion

This section outlined the research design and methodology deployed to answer the research questions. The chapter introduced Adaptive Theory and Social Domain Theory as modules within the methodological framework of Investigative Research, a methodology specifically designed to generate system concepts and theory from raw empirical data. The choice of this framework was motivated by the primary research objective to apprehend a systemic perspective of food waste creation in food chains. Furthermore, this section outlined the epistemological foundations of the research approach, which are congruent and compatible across the theoretical frameworks and adequate to the subject matter of multi-dimensional complex system phenomena and their emergent transformation over time. To answer research questions about practices, processes and characteristics of the horticulture supply chain, the methodology proposed an interview approach as primary form of data collection. The adaptive process of data sampling described the sampling criteria as diversity, priority and competence of research participants within the horticulture industry and showed how they were met through the actual research sample of 29 actors from the Australian horticulture industry. Empirical data collection was supported by an adaptive interview questionnaire addressing dominant practices of food waste creation, overproduction, and surplus, as well as potential solutions and ideas on the long-term sustainability of Australian horticulture. Finally, data analysis consisted of the three iterative-adaptive stages of provisional coding, satellite coding and conceptual bridging (see above Figure 2), with explanation relying on data analysis in relation to underlying social domains, specifically in regard to their capacity to control or transform social practice and phenomena. The methodology described three detailed

analytical levels that constitute the *qualitative interpretive core* of this inquiry, which are provisional and orienting concepts to guide data collection and analysis, multi-layered satellite maps to delineate and apprehend concepts, and conceptual bridging to enable explanation through social domain linkages.

This thesis now turns to the research output, specifically three research papers that address the three research questions (see section 1.4 above), present research findings and discuss their theoretical and practical implications for sustainable food systems.

3. The "Prevention Paradox": Food Waste Prevention and the Quandary of Systemic Surplus Production (Paper One)

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Preamble:

The first article addresses Research Question One, "How are the issues of food waste and food waste prevention framed in key debates globally?" The article is based on a comprehensive review of food waste literature focusing on emerging debates in key journals in recent years. Paper One reviews extant literature on food waste prevention and identifies three conceptual archetypes of food waste prevention, 1) preventing surplus from going to waste, 2) preventing consumers from throwing away food and 3) preventing waste from going to landfill. The three archetypes, or narratives, of prevention expose conceptual uncertainties about the purpose and nature of food waste prevention, which lead to the "prevention paradox". Considering alternative forms of food waste prevention beyond 'waste management' the paper discusses research on 'overproduction' as a potential cause of food waste and suggests that food waste prevention must address systemic phenomena, such as overproduction, to achieve an absolute reduction of waste.

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The "Prevention Paradox": food waste prevention and the quandary of systemic surplus production

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Abstract
Preventing food waste is a major global challenge to the sustainability and security of the environment, society and economy. In response to that challenge, a plethora of initiatives addressing food waste have formed in recent years. These initiatives focus on aspects such as the efficiency of resource use, reduction of supply chain food waste, food donations and rescue, consumer behaviour, and above all, innovative ways to add value to food surplus and waste. What many initiatives have in common is that they mainly deal with food waste once it exists rather than preventing it from occurring in the first place, which might thwart efforts to increase long-term food systems sustainability. The idea of food waste prevention itself is beset by several conceptual paradoxes: it is considered the most preferred method to manage waste—which it was supposed to prevent in the first place, and it is an ambiguous ecological behaviour lacking the tangible characteristics of waste composting or recycling (i.e. prevention by its nature is invisible). Most importantly, food waste prevention, like other major sustainability challenges, appears to be in a fundamental conflict of interest with current economic norms and practices. In response to these dissonances of prevention and the inability of waste management to reduce the creation of food waste, researchers have proposed a number of new approaches, including the re-appraisal of food overproduction as a key cause of food waste. Accepting Mourad's (Environ Soc Berkeley J Sociol 59:26–33, 2015) challenge to "think outside the bin", this work proposes a "Prevention Paradox" framing as a conceptual link between the bodies of research on food overproduction and food waste prevention, offering a more holistic approach to this major sustainability challenge.

Keywords Food waste prevention · The Prevention Paradox · Overproduction · Overconsumption · Sustainable food systems · Sustainable development goals

Abbreviations

EU	European Union
EC	European Commission
FAO	Food and Agriculture Organisation
FUSIONS	Food Use for Social Innovation by Optimising Waste Prevention Strategies
GDP	Gross Domestic Product
NGO	Non-governmental Organisation
SDG	Sustainable Development Goals
UNEP	United Nations Environment Programme
WRAP	Waste and Resource Action Programme
WRI	World Resource Institute

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Introduction

The food waste problem sits at the intersection of a number of global mega-issues, including climate change, unsustainable natural resource use, and what is often referred to as the "double burden" of hunger and obesity (Banwell and Dixon 2013, p. 298). At international and domestic levels, stakeholders generally agree that preventing food from becoming waste is the top priority in addressing food waste (see, e.g., European Commission 2008. Directive 2008/98/EC on Waste, [7]). Food waste prevention as an objective has

permeated the public consciousness and governance agendas only over the last decade. As a result, significant progress in reducing food waste has been made within very specific and local-level socio-political contexts (Aschemann-Witzel et al. 2015; Stensgård et al. 2018).

But more typically, responses by governments and industry have been largely symbolic (Corvellec et al. 2012, p. 302) and arguably based around a few marginal changes to business as usual (Mourad 2016, p. 468). For instance, Goal 12.3 of the United Nations Sustainable Development Goals (SDGs) is to halve food waste by 2030. Yet the approaches considered to achieve this target have not only been seen as lacking "effective guidance" (Bengtsson et al. 2018, p. 1), but also country reporting to the "SDG Index and Dashboards Report 2018" revealed that progress on achieving SDG 12.3 is a long way off the target (Sachs et al. 2018, p. viii). Consequently, a recent report by the UN Secretary-General on the Sustainable Development Goals acknowledged that the process of reducing food waste was "challenging" and in need of a "profound transformation" (UN Economic and Social Council 2018, p. 16).

In considering the kinds of governance arrangements required for such a transformation, this paper begins with a critical examination how food waste is problematised and especially how food waste prevention, as the top priority in addressing food waste, is framed and pursued. We show how food waste prevention has been subsumed into measures aimed at diverting or averting waste.

Prevention, therefore, is not being conceptualised as genuine prevention of food waste. Rather, prevailing conceptions of food waste prevention that are embodied in the widely used food waste management hierarchy are a tacit acceptance of the inevitability of excess food and food waste. How we understand food waste prevention determines how we respond to it. By grouping food waste prevention with all other waste management approaches, the associations between food waste and broader food system dynamics have largely been obscured and neglected. Further impeding progress on food waste prevention are the underlying conceptual uncertainties concerning the nature of the food waste and how "prevention" can be known i.e. measured and enabled (Chaboud and Daviron 2017; Corrado et al. 2019).

To address these limitations in current food waste theorising, the following section of the paper proceeds to identify the key conceptual and practical dissonances surrounding the theory and practice of food waste "prevention". Challenges embedded in pursuing food waste prevention are explored by considering ontological uncertainties, existing levels of investment in waste management infrastructure, ideological dependencies and social values associated with production, consumption, liberty and personal freedom.

The final part of this paper unpacks and problematises key contradictions between food waste prevention and the prevailing socio-economic system. In doing so, this paper argues that surplus food production in excess of demand is a fundamental condition of dominant food systems. These large-scale increases in supply, combined with the ongoing rise of food mass retailing and related dietary transitions, have contributed to food waste creation and overconsumption along the entire food supply chain.

We coin the term "Prevention Paradox" and propose that prevailing mainstream narratives of food waste prevention often fail to genuinely capture the prevention of food waste at the source. In linking the bodies of research on food waste prevention and overproduction, we consider ways toward a more holistic approach to understanding and addressing unsustainable food system outcomes including food waste.

The conceptual and material paradox of prevention in food waste management

There is now a burgeoning literature on the causes and solutions to food waste. Despite the seeming intractability of the food waste problem, its context-specific causes are largely agreed upon and have been comprehensively studied. Systematic inventories pinpointing hundreds of single food waste causes have been presented in official publications by government, non-governmental organizations (NGOs) and international agencies. Key bodies synthesising and disseminating the proximate causes of food waste include the Food and Agriculture Organisation (FAO 2011), the United Nations Environment Programme (UNEP 2015), the NGO Waste and Resources Action Programme (WRAP 2018), and the European Commission's "Fusions" project (EU FUSIONS 2016). Additionally, a growing body of scientific literature has exhaustively documented the wide-ranging causes of food waste along the food supply chain. These causes include disruption by unpredictable events such as changes in demand, inefficiencies in manufacturing processes, lack of coordination among supply chain actors, food degradation during transportation, food standard regulations, and commercial practices of excessive demand stimulation through aggressive marketing practices (Alexander et al. 2017; Bernstad et al. 2017; Canali et al. 2013; Devin and Richards 2018; Muriana 2017). The establishment of the "Food Loss and Waste Protocol" (WRI 2016) as a global multi-stakeholder framework represented a significant step towards harmonization of various food waste definitions, standards and reporting guidelines. Importantly, the protocol replaces problematic distinctions in, and a lack of consensus regarding, terms such as "loss" and "waste" (Bernstad et al. 2017; Chaboud and Daviron 2017; FAO 2011) or "avoidable" and "unavoidable" (WRAP 2018). A more flexible and context-dependent understanding of these terms has

emerged with standards and guidelines based on the final destination of material flows.

Within the more specific debates about causes, definitions and measures of food waste, broader conceptual and practical dissonances between waste prevention and waste management become evident. How food waste is defined, classified and measured changes how the problem of food waste is understood, compared and addressed. The EU, for instance, measures food that is thrown out by consumers, retailers or producers but does not measure food by-products diverted to animal feed. Thus, little is known about how much food is diverted to animal feed, and how much of this food/feed that is intended for humans is then consumed by non-human animals (Corrado et al. 2019, p. 94).

Similarly, the use of food to produce animal feed as well as biofuels, referred to as "non-human agricultural production", is left out of such accounting (Chaboud and Daviron 2017, p. 4). This means what could be considered key waste streams diverting food from human consumption, are not within the purview of food waste or its prevention. By contouring food waste accounting in these ways, it is difficult to obtain a complete idea of how much food is produced for humans and then not actually consumed by humans. A lack of knowledge about the extent of the problem prevents discussion about how to respond to food waste's various other, interrelated dimensions including: the adverse dietary and environmental impacts of livestock production (Alexander et al. 2017; Kummu et al. 2012); the desirability of biofuel production over other renewable energy sources in terms of environmental impacts (Götz et al. 2017; McMichael 2010) and the problem of the overconsumption of food associated with the prevalence of diet-related non-communicable diseases worldwide (Alexander et al. 2017, p. 190; Papargyropoulou et al. 2014, p. 108; Vandevijvere et al. 2015, p. 446; Vulcano and Ciccarese 2017, p. 9). By isolating food waste from other activities affecting food system sustainability, the strategies open to decision-makers in preventing food from existing only to be wasted are significantly reduced.

In regards to "open" strategies, the "food waste management hierarchy" is the predominant framework used to conceptualise and address food waste across government, industry and the third sector. On the food waste hierarchy, the most preferable category of prevention is followed by re-distribution to people, waste transformation (e.g. feeding to animals, valorisation, energy recovery, composting), and finally disposal in a landfill. Landfill disposal is invariably the least-preferred option for waste management and should only be employed when all other avenues are exhausted (Marin et al. 2014; Papargyropoulou et al. 2014; Salemdeeb et al. 2017a; Van Ewijk and Stegemann 2016). Food waste is represented by its own food waste management hierarchy largely because food differs from other waste (such as solid waste) as it is organic and highly perishable, is largely compostable in the right environment and fulfills a basic and universal need (Bloom 2010; Mourad 2016).

Prevention, i.e. source reduction, tops all major waste management frameworks and is recognised as the highest priority in food waste management (Corvellec et al. 2018; Hutner et al. 2017; Van Ewijk and Stegemann 2016; Zorpas and Lasaridi 2013). In other words, when designing ways to respond to food waste decision-makers should prioritise actions to avoid producing food that will not be utilised, and in doing so, reducing the unnecessary use of resource inputs such as water, fuel and labour.

Prevention is preferred because it is the only option that saves natural resources from being used unnecessarily, whereas all other options respond to food waste after it has been produced. Preventing food waste before it happens has the potential, therefore, to reduce the consumption of energy, water and other resources associated with production, transportation, storage, and preparation embodied in food waste (Cuellar and Webber 2010; Hoekstra 2012; Quested et al. 2013; Vittuari et al. 2016). Equally, food waste prevention avoids direct and indirect waste impacts such as packaging, effluents as well as the greenhouse gas emissions caused by the production, management and disposal of food waste (Kummu et al. 2012; Vermeulen et al. 2012).

Accordingly, prevention has a role in not only mitigating environmental harms but also in addressing the threats to food security and food system sustainability posed by climate change and natural resource depletion (Berry et al. 2015). Strategies to prevent food waste to the extent that meets the aspirations of the SDGs need to address the overproduction of food in the global food system and overconsumption of food beyond that required to meet energy needs, which is a global dietary trend associated with diet-related non-communicable diseases (Friel et al. 2014).

While prevention is regularly hailed as the undisputed policy priority of waste management, the act of preventing waste is significantly different in nature to the act of dealing with existing waste (Corvellec et al. 2018). A generally accepted definition of waste management is: "the collecting, treating, and disposing of solid material that is discarded because it has served its purpose or is no longer useful" with the term "waste" applying to material products (see, e.g., Nathanson 2018). As this understanding illustrates, waste management does not infer actions to prevent waste material but rather actions that address existing waste material. Correspondingly, prevention stops waste from needing to be managed, highlighting the ontological dilemma flagged earlier, that is, a food waste management hierarchy assumes materiality (the existence of something that might be wasted), whereas prevention in its truest meaning, does not.

Compared with physical management or transformation of real and tangible waste then, prevention has different

ontological quality. After all, it is difficult to delineate prevention since it is challenging to comprehend what did not occur or exist (Zorpas and Lasaridi 2013, p. 1047). The real problem apparently is the waste itself; once it is there it is too late for its prevention (Corvellec et al. 2012, p. 300). Hence, in less philosophical terms, using prevention to manage waste is akin to "fixing a flat tyre by reminding someone to avoid nails" (Bloom 2010, p. 145). The conceptual dissonance between preventing waste and managing waste once it exists suggest that waste prevention requires an entirely separate range of activities from waste management (Zacho and Mosgard 2016).

If "prevention" is not a material and substantive method of waste management, then its inclusion in the waste management hierarchy is indeed problematic. Waste management has attracted highly significant levels of investment in its research and development, while preventative efforts have been arguably under-studied and under-developed (Corvellec 2016). The waste management industry has captured substantial investment into infrastructure and technologies, which has a reinforcing effect on how food waste is framed and communicated as something to be managed rather than avoided at the source. This observation is supported by Thyberg and Tonjes (2016), who note that waste prevention has been ignored by states in favour of a focus on recycling and diversion.

It can be argued that the socio-technical structures currently in place to address waste management, generate a "lock-in" (Geels et al. 2014) to systems that manage rather than prevent waste. Further, the resources and systems dedicated to waste management serve to impede the paradigm shift necessary for non-material food waste prevention (Corvellec 2016, p. 7; Zacho and Mosgaard 2016, p. 990), that is, through preventing the overproduction of food in the first place. An adjusted focus away from food waste management to food waste prevention conceived as a reduction in material throughputs and waste (Van Ewijk and Stegemann 2016) thus contradicts the socio-technical waste management regime. Prevention does this by not only seeking to reduce the levels of waste to manage, but also by contesting, and perhaps undermining, the need for investment in waste management.

Besides physical infrastructure and investments reinforcing a focus on waste management over waste prevention, the rules, customs, actors and signals that regulate societies are ill-suited to preventing over-production in the first place. Even before markets were increasingly liberalised from the 1980s onwards, regulatory measures to reduce the number of consumer goods being produced was uncommon, unless the goods and services posed an immediate and direct threat to human or societal well-being and garnered enough political support for intervention. Rather, continually increasing levels of production have been incentivised through government supports and market mechanisms based on economies of scale. Moreover, the freedom to produce and to waste (Stuart 2009, p. 203) is protected via national and international legal regimes. Waste prevention strategies could, for instance, violate international trade and investment law (Li and Zhao 2017). Meanwhile, a cultural and social emphasis on consumption and a free-market fundamentalism ideology condone and rely upon a system of obsolescence and waste generation to further economic growth (Carolan 2018; Meadows, et al. 1972; Patel 2007).

Having outlined the conceptual and practical underpinnings of what we term the "Prevention Paradox" and its inherent contradictions, this research will proceed to a critique of mainstream approaches to food waste prevention. Accordingly, the next section reviews prevailing food waste prevention approaches paying close attention to overcoming the Prevention Paradox.

Unpacking the "Prevention Paradox"

We present the 'Prevention Paradox' as the contradiction between the following two dimensions: The publicly-proclaimed preference for "food waste prevention" versus industry and government responses to food waste, which focus upon managing rather than preventing. The Prevention Paradox seeks to draw out the material and ideological constraints that underlie this contradiction and the conflicts of interest, which hinder food waste prevention from being genuinely pursued. It unpacks how governments and industry prioritise food waste prevention on paper, and how their failure to prioritise preventing the creation of waste contributes to increased waste generation.

To evidence these claims, the following sub-sections demonstrate the ways in which the Prevention Paradox is conceptually and practically present within three main archetypes of food waste responses, which sit on different levels along the waste hierarchy. These are: "preventing surplus food from becoming waste", "educating consumers not to throw away food", and "zero waste (to landfill)".

Preventing surplus food from becoming waste

In relation to the first prevention paradigm, i.e. preventing surplus food from becoming waste, food surpluses exist at all stages of the food supply chain including farming, manufacturing, logistics, retail, and foodservice (Alexander et al. 2017; Bernstad et al. 2017; Göbel et al. 2015). Overproduction and surplus are necessary, perhaps even intended outcomes of the present food system to safeguard against supply chain risks and to satisfy trade and consumer demand (Papargyropoulou et al. 2014; Raak et al. 2017). Importantly, empirical evidence shows a very close relationship between

food surplus and food waste (Hic et al. 2016; Vulcano and Ciccarese 2017) and consequently Papargyropoulou et al. (2014) have emphasised the importance of minimising food surplus for sustainable solutions to food waste.

Researchers and practitioners regard food surpluses as an issue that can be addressed via improved food chain governance (Canali et al. 2013; Garrone et al. 2014). Thus, the focus has been, for instance, on reducing errors in production planning, inventory management, and packaging and labeling, which cause otherwise perfectly edible food to become surplus and ultimately waste (Garrone et al. 2016; Mena et al. 2011; Midgley 2013). Surplus and waste are also created within the production process itself due to steps such as cutting, trimming, packaging, equipment change-over as well as cosmetic standards such as size and shape (Devin and Richards 2018; Midgley 2013; Parry et al. 2015; Raak et al. 2017).

As a result of the focus on food surpluses as a food chain governance issue, "surplus management" has been cited as a distinct capability of food system actors, resting on the dual pillars of "surplus control systems" as well as the "cooperation with food rescue organisations" (Garrone et al. 2016, p. 1076). Food system actors undertake surplus control by developing capabilities to anticipate, recognise and respond to surplus before or as it occurs. Surplus management refers to the activities undertaken once the surplus begins to form at some stage of the food system, namely disposing of the surplus via secondary channels and discounting and promotion.

Large retailers, for example, use a high-volume mass distribution business model, which inherently enables the movement of very large amounts of food surplus further down the chain into households. Calvo-Porral et al. (2016, p. 57) describe the mechanisms involved in such surplus transfers, including multi-buy promotions, upsizing coupons and high-pressure advertising campaigns. Importantly, they found that stopping such advertising and marketing strategies activities would result in food waste reduction at the household level. Additionally, food retailers, due to their significant capabilities and influence over the entire food supply chain, are uniquely well-positioned to cause significant reductions in food waste. Indeed, Young et al. (2017) described the highly positive effects of retail mechanisms and communication in influencing consumers on food waste reduction. However, the researchers conceded that it is in the retailers' natural interest to sell more product and not to address issues of mass consumption and its associated waste (Young et al. 2017, p. 12). Indeed, retail mechanisms, interdependent with consumer responses, have resulted in prevailing consumption norms of oversupply and abundance that are highly conducive to waste creation (Pedersen et al. 2015, p. 14; Raak et al. 2017, p. 463). Hence, the ways in which retailers operate, and the context of so-called consumer choices, again serves to illustrate the Prevention Paradox at work.

Moving upstream into the supply chain to processing and manufacturing, surplus management also refers to the reuse the unavoidable surplus of ingredients or by-products through "up-cycling" into new innovative products (Bhatt et al. 2018; Lin et al. 2013). This method to create value-added products seeks to exploit the "food surplus resource" (Midgley 2013). However, as will be discussed in the context of landfill prevention further below, the treatment of food surplus or, inadvertently, food waste as a resource can have a perpetuating effect on surplus creation and thus contradict preventive and reductive approaches of surplus avoidance, hence reflecting another tension in preventing waste (Raak et al. 2017).

A dominant surplus management strategy, particularly in recent years, has been for major food suppliers and retailers to work with food rescue organisations to redistribute surplus food. Such initiatives include food rescue, food banks, food donations, social supermarkets, and a variety of different approaches to redistribute surplus food from manufacturers, retailers, and foodservice institutions (Booth et al. 2014; Evans et al. 2012; Garrone et al. 2016; Lebersorger and Schneider 2014). Whilst some would argue that the food waste/food relief nexus highlights problems in both in terms of the food system dysfunction and growing income inequality (Richards et al. 2016; Devin and Richards 2018), others have noted that surplus food donation is a desirable and just method of managing food surplus (Garrone et al. 2016). Surplus food donation is often approached from a normative standpoint, reflecting the immediacy of need for those seeking food relief, and the visible excess food that would ordinarily reach landfill. In the absence of alternatives to both growing income inequality (Piketty 2014) and the food waste problem, the practical and charitable principles of donating food rather than throwing it away have been largely embraced by supply chain actors, academics, policymakers and civil society (Mourad 2016; Lebersorger and Schneider 2014).

Empirical research regarding food re-distribution initiatives in developed countries further supports food waste redistribution with findings that such schemes make a positive contribution to economic, social, and environmental sustainability (Hoisington et al. 2001; Mirosa et al. 2016). However, there are also detracting voices that question the extent to which this dumping of excess food onto socio-economically marginalised populations addresses the dual and related issues of food waste and food security. For instance Booth et al. (2014) noted that at best food rescue and re-distribution is a band-aid solution, whilst Richards et al. (2016) argue that neoliberal rollback in countries such as Australia has reduced social issues such as poverty and

hunger to a new space for the expression of corporate social responsibility in an essentially dysfunctional food system.

Despite the growing attention on food rescue and food relief, only a small percentage of excess food is actually donated by corporations. Not all surplus food is donated, and not all hungry people are fed. A study by Lebersorger and Schneider (2014, p. 1914) on 612 supermarkets in Austria states the amount of food donated as low as 2.3% for the fruit and vegetable category and about 7% on average across other categories such as bread, dairy and packaged foods. While the absolute impact of redistribution on food waste prevention might be modest, it is an important initiative for highlighting the problems of food waste and responding to immediate household food security.

In sum, the understanding of food surplus causes and its prevention as a supply chain management issue focuses on efficiency, innovation, and charity. A closer look, however, revealed that the methodologies suggested for their preventive potential are more essentially focused on surplus disposal rather than avoiding surplus from existing. Ultimately, treating and measuring prevention as if it is efficiency in surplus disposal reinforces, perhaps even encourages, producing more surplus.

Educating consumers not to throw away food

The concepts of consumer education and behavior change are the predominant approaches to food waste prevention. Indeed, academic literature and official reports have implicated the consumption phase as the largest contributor to food waste in Western developed countries (Aschemann-Witzel et al. 2015; Calvo-Porral et al. 2016; FAO 2011). A comprehensive literature review by Principato (2018) is entirely dedicated to "Food Waste at Consumer Level" and pinpoints the lack of consumer awareness as well as related incorrect behaviour as the key reasons for consumers wasting food. Once consumer education and behavior is identified as the cause, the logical solutions put forward centre on practical interventions into everyday lives of consumers and their decision-making processes as well as social campaigns (Principato 2018, p. ix). Consequently, the emphasis in this paradigm is placed on personal responsibility and influencing how it is exercised.

Certainly, consumers and households are one of the points along a value chain where food is wasted, and so initiatives to influence personal food waste are important. Yet the emphasis on consumers is disproportionate. Some suggest the early focus on household surveys and waste composition analysis resulted in comparatively high levels of data on consumer and household food waste (Campbell et al. 2017; Höjgård et al. 2013; Van der Werf and Gilliland 2017). Another reason why the emphasis on consumer and household food waste is disproportionate stems from the position of the consumer at the end of the supply chain. All the cumulative effects from production, transportation, storage, and retail can be measured in the food wasted by consumers, thus creating a higher environmental impact compared to products wasted earlier in the supply chain (Bernstad et al. 2017). There is also, potentially, cultural tendencies among consumers to feel guilt and anxiety about their food waste that support the emphasis on personal responsibility (Evans et al. 2012). Arguably, these various factors contribute to the impression, particularly in popular discourse, that consumers and households should be the main group targeted if food waste is to be reduced (Campbell et al. 2017; Principato 2018; Quested et al. 2013; Vermeulen et al. 2012).

The strong emphasis on consumers and households as the key to solving the food waste problem is prominent in food waste discourses, but it is by no means universally accepted. In his aptly titled article "Blaming the consumer—once again", Evans (2011) disagrees with the proposed view of food waste as a consumer behavior problem. He joins other researchers in arguing that the social and material conditions of food consumption and the impacts of the prevailing food system on consumer behaviour need to be taken into account as well (Carolan 2018; Chaboud and Daviron 2017; Quested et al. 2013; Mylan et al. 2016; Urrutia et al. 2019).

In response, research has focused on consumer impacts from supply-side mechanisms such as purchase inducements, choice editing, smart defaults, and strategies of advertising communication, which utilise cognitive biases in humans (O'Rourke and Lollo 2015). Indeed, the findings suggest that a substantial part of consumer waste is generated by practices upstream, such as packaging, promotional offers, restaurant portions sizes, fast food consumption habits, and overprovisioning (Butler and Dixon 2012; Evans 2011; Göbel et al. 2015; Langen et al. 2015; Mylan et al. 2016). This indicates that food waste creation at the household level cannot be explained by consumer behavior as a sole cause, but has to be regarded within the structural context of the whole food supply chain.

We take as an example the fact that consumers buy more than they need, which has been cited as a behaviour leading to food waste (Quested et al. 2013). It may be argued that the appropriate response, in that case, should be to teach consumers not to purchase waste rather than not to throw away waste. It may also be questioned whether teaching the consumer is at all a salient approach to the problem of overpurchase. Critical food scholars like Dixon (2002) and Parker (2014) described the comparative lack of power of consumer purchase choice versus retail marketing mechanisms as a series of inconsequential decisions and a fallacy. Concerning the impact of available supply upon consumer behaviour, Chaboud and Daviron (2017, p. 5) argue that it has not been shown conclusively how reduced consumer purchases and

reduced household waste will result in reduced production and natural resource use further up the supply chain.

The excessive focus on consumer behavior and education is an example of the Prevention Paradox. Influencing consumers to throw away less food does not necessarily or directly result in an absolute reduction in food produced only to be wasted. Rather, the narrative of prioritising teaching, nudging or forcing consumers not to throw away food leads to a reductionist understanding of food waste that distracts from broader food system dynamics including an economic system built upon aggressive marketing alongside neoliberal ideologies of unfettered growth.

Circular economy and zero waste (to landfill)

The third paradigm entails diverting organic matter to prevent it from going to landfill and it centers around the concepts of "zero waste" and "circular economy". The framing of "zero waste" arose from the EU landfill directive (European Commission 1999), which understood "zero waste" as "zero waste to landfill". During this period, other countries and international institutions adopted "zero waste to landfill" and landfill prevention policies (Bloom 2010; Evans et al. 2012; Ghisellini et al. 2016; Zaman 2015). Since this time, landfill diversion has become a core target for waste managers in many countries with the "diversion rate" still widely used to measure success in combatting waste (Zaman and Lehmann 2013).

The more recent concept of a circular economy seeks to shift linear production and consumption systems towards keeping materials in use, which approach has been embraced by states (e.g. the EU and China) and international institutions (Zacho and Mosgaard 2016; Zaman and Lehmann 2013). Similar to zero waste, circular economy approaches focus on recycling and reuse, and it also uses landfill diversion rates as a key measure. These concepts are useful for waste management and do denote some kind of waste prevention i.e. that the goal is to reduce the extraction of natural resources indirectly by reusing and recycling waste. Although zero waste and circular economy approaches are holistic, systematic literature reviews find they tend to be narrowly interpreted in practice as largely aimed at reducing landfill while systems-change is often not emphasised (Zaman 2015; Kirchherr et al. 2017).

As the success of these approaches rely on the amount of food diverted, the responses have tended to focus on enabling innovation and technological developments to repurpose end-of-pipe food waste, often referred to as waste transformation of food waste valorisation (Ghisellini et al. 2016; Mena et al. 2011). As mentioned above, a favoured approach is to turn food waste into animal feed (Salemdeeb et al. 2017b). Another solution as mentioned above in the context of food surplus is upcycling into what Bhatt et al. (2018) refer to as "value added surplus products". These are beneficial products, which can be extracted from food surplus and waste. Raak et al. (2017) have presented a review of commodity-specific waste prevention and value-adding approaches, which address a variety of food processing by-products, surplus products and waste, all of which pose different operational challenges to extract value. Crucially in this context, value-adding is not just an ad-hoc waste management or prevention measure. Rather it requires an underlying business model that considers the source of inputs, the processing and packaging equipment needed, and successful marketability of the resulting valorised products. Further, there is evidence that depending on specific types of waste and manufacturing processes, such as micro-nutrient extraction for the health supplements industry, only small amounts of surplus are captured with the balance destined for landfill (Mehta et al. 2014). Because such approaches rely on substantial investments into waste to generate value, those socio-technical systems in place to transform waste may ultimately demand and encourage the continuous and reliable supply of surplus and waste (Raak et al. 2017, p. 467).

Energy generation is another popular form of advanced waste transformation. Food waste generates energy through processes such as incineration or anaerobic digestion. Compared to composting food waste to recover nutrients, which produces "dirt instead of energy" (Bloom 2010, p. 259), industrial energy recovery is a significant technological and infrastructural step-up. However, research has also shown that a significant part of the energy from food waste is irrecoverable due to the "double energy" embodied in food waste, the *non-consumed* nutritional energy combined with the energy *consumed* to make the food (Vittuari et al. 2016, p. 2).

Preventing organic waste from entering landfill may address one source of highly negative environmental impacts of food waste i.e. greenhouse gas emissions (Marin et al. 2014; Vermeulen et al. 2012). Yet, there are still significant trade-offs and barriers to zero waste circular economy approaches. Food waste treatment and recovery requires costly infrastructure, technology, economies of scale, investment, and returns on investment. It does not, however, reduce the amount of food waste generated—but presents a more palatable conceptual shift where waste is no longer seen as an output or externality but as a resource and input into energy production. The technological and commercial optimism of creating a business around food waste may thus even contribute to more waste as the market mechanisms require a supply of food waste to achieve viable volumes for investment and production (Bloom 2010, p. 279; Corvellec et al. 2012, p. 303). This is partly because the costs of goods may decline as reused inputs cost less. Further, the emphasis on technological transformation and disposal of waste (Evans et al. 2012, p. 22) contributes to a normalization of

unsustainable production and consumption while preempting questions of responsibility and social license to create waste (Corvellec et al. 2018, p. 18).

By emphasising the limited ways in which dominant approaches to waste prevention focus on responding to the material presence of waste, it is argued here that no approach has been developed for implementation that primarily seeks to reduce waste in absolute terms. Thus, the approaches that do exist could be a distraction from food waste prevention by promoting competing methods (Mourad 2016) or even a hindrance of food waste prevention by committing long terms investments to waste transformation or disposal infrastructures (Corvellec 2016). Having addressed the food waste Prevention Paradox and three distinct but problematic conceptions of food waste prevention, the next section turns to an exploration of the relationship between the overproduction of food and food waste prevention, an area that is currently under-theorised and absent from key debates, despite the well-established need for the prevention of food waste.

Addressing food surplus, food waste and avoidance of overproduction

The previous section addressed how prevailing prevention paradigms are to different extents succumbing to the Prevention Paradox. While they appear to be prevention strategies, the broad types of approaches are rendering them incapable of directly addressing the avoidance of food waste creation in the first place. It follows that a broader, holistic, whole system approach is necessary to address the problem of food waste at the source. To do this, it is important to understand the historical evolution of the agri-food sector, which has led to the current outcome of excessive food waste.

An emerging focus in the food waste literature looks beyond internal supply chain dynamics by positioning food waste as a problem of overproduction (Bloom 2010; Chaboud and Daviron 2017; Evans et al. 2012; Mourad 2016; Pritchard 2012; Weis 2007). Situated firmly in the global political economy of food and agriculture, the overproduction thesis maintains that food produced in excess of demand promotes both overconsumption and waste. Both of these outcomes have been observed by researchers and have been strongly associated with negative impacts on health and the environment (Hall et al. 2009; Hic et al. 2016; Vandevijvere et al. 2015; Vulcano and Ciccarese 2017; Weis 2007). Overproduction represents a well-known area of scholarship into global food systems, generally with an emphasis on agricultural dumping, aid, trade and global geopolitics (Clapp 2014; McMichael 2009; Pritchard 2012), but has only recently been posited as a key influencing factor of food waste, with more work needed to fully explore these dynamics.

The structural overproduction in food systems received focused attention in the work of critical political-economists, Friedmann and McMichael (1989). Their theory recounts the rise of a post-war food regime, which was aptly described as a "chronic and expanding state of surplus" (Weis 2007, p. 63). Technological advances, cheap fossil fuels and sustained public subsidies, predominantly in the US and Europe, drove food production to historically unprecedented surplus levels (Pritchard 2012; Weis 2007). The continued escalation of food production was realised by fast growth of output volumes and also by concentrated industrialisation primarily achieved through the accelerated production of livestock and durable processed foods (Evans et al. 2012; McMichael 2009). The invisible fats and the unneeded and low-cost nutrition surplus (Butler and Dixon 2012) in turn produced consumption levels "inconsistent with healthy bodies, societies, and cultures" (Friedmann 2008, p. 618). The run-away food production of the last half century has no longer been bound by the purpose of feeding people food to meet their nutritional needs, by market demand or by the necessity to create sufficient safety stocks to secure food availability (Papargyropoulou et al. 2014). Food production has simply carried on for its own sake and the accumulation of capital (Pritchard 2012). Accordingly, the overproduction of food has become entirely normalised as the prevailing and likely the only known mode of production and consumption in developed, and increasingly middle-income, countries (Mourad 2016; O'Rourke and Lollo 2015; Weis 2007).

The relationship between overproduction and food waste has been considered by researchers examining different food production systems and comparing the waste generated as one of their outcomes (Parfitt et al. 2010; Vulcano and Ciccarese 2017). Based on studies in the EU, this body of work provides evidence for the fact that industrial agricultural production and distribution models produce a significantly higher rate of waste than contrasting short and alternative supply chains (Vulcano and Ciccarese 2017, p. 41). These findings belie the intuitive claim that large-scale, industrial agri-food systems are the most resource efficient (Ericksen 2008; Parfitt et al. 2010) and add to the substantial existing evidence that alternative food systems tend to produce more sustainable outcomes (Burch and Lawrence 2005; Carolan 2018; Dixon and Richards 2016). Food waste is, therefore, interwoven with dominant modes of food production and food system designs that depend upon chronic oversupply.

Some studies sought to quantify the scale of food surplus. Hic et al. (2016, p. 4269) analysed data on the amount of food physically available on a global scale against the different projections of human nutrition requirements. Their research indicated that current levels of food surplus intended for human consumption alone (i.e. not including animal feed and biofuels) already exceed nutrition requirements by approximately 20%. Most alarmingly, however,

since food production has been outpacing actual food (over) consumption, which is already in excess of, and growing faster than, nutritional requirements, the growing future surplus is expected to be predominantly "generating food waste rather than further overconsumption" (Hic et al. 2016, p. 4275). Thus, it appears that global food production will increasingly find its purpose in producing food waste rather than feeding people—the natural landing point for an economy based on continued growth.

The amount of food surplus closely corresponds with the trend-line of the world population classified as obese and with the upward trend for food waste generation (Hall et al. 2009; Vandevivjere et al. 2015; Weis 2007). Indeed, some scholars consider the problem of food waste as a problem of food surpluses (Carolan 2018; Papargyropoulou et al. 2014; Vulcano and Ciccarese 2017; Weis 2007). Of course, correlation is not causation. Yet, this research, especially in the context of the systems-based understanding of food processes, evidences close interrelationships between the prevalence of diet-related NCDs, food waste and food surplus generation. In studying these interrelationships further, scholars have provided various understandings. For instance, Hall et al. (2009, p. 2) suggested that the "food intake in the US has been unable to match the increasing physical availability of cheap food", and processed foods in particular, resulting in a "progressive increase of food waste".

If systemic and endemic overproduction is a significant contributing factor to the food waste problem, prevention of surplus food production or "supply restraint" (Weis 2007, p. 63)[1] should have the potential to deliver equally significant social and environmental benefits (Quested et al. 2013; Van Ewijk and Stegemann 2016; Vulcano and Ciccarese 2017). The key debate in the food waste prevention literature does not, however, consider the environmental benefits of supply restraint as much as the impacts that reducing or avoiding food production might have on the economic system as a whole (Mourad 2016; O'Rourke and Lollo 2015; Rutten 2013).

Economic theorists evaluate positive and negative net outcomes by applying a method of theoretical modeling, which allows for a comparison of a variety of food waste prevention variables. Some research in this specific field indicates significant positive outcomes from supply restraint as a measure of food waste prevention for areas such as greenhouse gas emissions, household income and agricultural land use with positive flow-on effects for economies and societies (Parry et al. 2015; Rutten et al. 2013). It has been argued, however, that the benefits of supply restraint cannot be assessed merely as the equivalent of the avoided resource use, as a host of other intended and unintended impacts must be taken into consideration (O'Rourke and Lollo 2015; Rutten et al. 2013). Some economists assert that the potential overall benefits of supply restraint as a measure of food waste reduction are overstated once economic counter-effects such as increased use of alternative resources and compensatory impacts like the "rebound effect"[2] are fully taken into account (Höjgård et al. 2013; Köster 2014; O'Rourke and Lollo 2015; Salemdeeb et al. 2017a).

Theoretical modeling has suggested that a broader systemic approach, such as influencing populations to adopt healthier diets, would result in more sustainable environmental and economic outcomes than a single-minded focus on supply restraint to reduce food waste. Without even considering the long-term gains from improved public health, adopting a healthier diet has arguably less negative impact on GDP and a highly positive environmental impact in terms of reduced agricultural land-use (Rutten et al. 2013, p. 11). Moreover, considering the close relationship between unhealthy diets and food waste generation, a systemic approach of promoting healthy diets is likely to cause food waste reduction as a side-benefit.

Apart from specifically environmental and economic consequences, measures to restrain production and consumption as a means of preventing food waste would also impact, and come up against, societal customs and norms (Mourad 2016; Mylan et al. 2016; O'Rourke and Lollo 2015). Customs and traditions often encourage the over-supplying of food, especially around celebratory events, and may be adversely affected by measures to restrict production and consumption (Parfitt et al. 2010). Mylan et al. (2016, p. 4) argue "society is accustomed to a life that requires a multitude of materials and services. A detailed examination of the practices of daily life brings to light the problems consumers face in even changing quite mundane parts of their life". Surplus production and the over-consumption of food are associated with diet-related, non-communicable disease. Banwell and Dixon (2013, p. 298) offer the term "consumptogenic environments", to demonstrate how high levels of consumption are encouraged and condoned by external factors like food marketing, food retail strategies and the loss of clear cultural norms around eating as diets converge and become more Westernised (Banwell et al. 2012; Banwell and Dixon 2013). The changes required to depart from the production and consumption mechanisms deeply ingrained within the prevailing food surplus regime go beyond what the efforts of

[1] "Supply restraint" can be described as a set of interventions to prevent supply from exceeding demand, thus avoiding unneeded surplus production.

[2] The "rebound effect" or Jevon's Paradox describes the negative consequence of increased consumption resulting from resource efficiency gains (e.g. O'Rourke and Lollo 2015, p. 241).

consumers alone can achieve (McMichael 2009; Principato 2018).

It would be a mistake, therefore, to focus on supply restraint solely as a technical means of preventing food waste, simply by reducing production amounts. Any efforts to constrain supply must be also complemented by a change of social and cultural practices and values. Accordingly, the kinds of transformation required to address food waste will involve changes to behavior, culture, infrastructure and economic values in a holistic and integrated way (Canali et al. 2013, p. 17; O'Rourke and Lollo 2015, p. 252).

Discussion and conclusion

In response to the UN Secretary General's call for "profound transformation" (UN Economic and Social Council 2018), this paper has proposed a more holistic understanding of food waste prevention beyond the confines of waste management. Arguably, cultural values around food, an economic paradigm grounded in the concept of continued growth and investment in food waste management infrastructure, have enabled a socio-technical lock-in to a structure that manages rather than reduces food waste. Couple this with the ontological difficulties of measuring absolute prevention, or in other words, measuring something that is not there, and absolute prevention may be difficult to attain. Despite this, if aspirations of food waste reduction are to be achieved, a re-articulation of food waste and loss and its prevention are necessary. This requires recognition and acceptance of the problem of structural overproduction and overconsumption.

By highlighting the contradictions in approaches that aim to prevent surplus going to waste, educate consumers, and achieve zero waste to landfill, the "Prevention Paradox" supports a conceptual reorientation towards overproduction and overconsumption. Research on food surplus indicates that the possibility of prevention as absolute reduction exists, but this approach lacks ideological support and clear implementation methodologies. Considering the conceptual uncertainties that underpin food waste prevention, there is a need to advance the theoretical and practical understanding of what large scale food waste prevention beyond waste management should constitute. This involves an ontological and normative enquiry to clarify what is being wasted, what is being prevented, what absolute reduction should mean, and how it is justified in relation to sustainable food systems and finite limits to growth (Clapp and Swanston 2009; Corvellec et al. 2018; Sandberg et al. 2019; Savaget et al. 2019).

Based on a more open and holistic understanding of food waste prevention, new approaches and methodologies outside of the prevailing waste management paradigms are required to better enable sustainable production/consumption. Either way, we argue government and industry need to identify responses to overcome the systemic socio-economic quandaries described by the "Prevention Paradox" to get more traction. This might imply that sustainable solutions will have to address substantial trade-offs rather than acquiesce to business as usual. The nascent literature that links the well-trodden areas of food waste and overproduction may well be the pathway to understanding the root causes of food waste. Given the economic hegemony of the unfettered growth paradigm, this approach will not be without controversy—however, the increasing acceptance of the "limits to growth" argument will necessitate a space for such debates.

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4. From Surplus-to-Waste: A Study of Systemic Overproduction, Surplus and Food Waste in Horticultural Supply Chains (Paper Two)

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Preamble:

The second paper proposes a systemic perspective of food waste, which considers food waste as inherent to food system processes. Addressing research and knowledge gaps in relation to the systemic creation of food waste within food systems, this paper mainly responds to Research Question Two, "What dominant practices and processes cause food waste at the production stage in the Australian horticulture industry? and "How does overproduction contribute to food waste?" This paper reports empirical and theoretical findings on the phenomenon of 'overproduction' identifying the processes, mechanisms and system characteristics that lead to the creation of systemic food waste. By drawing on Socio-technical Transition Theory systemic food waste is conceived of as a 'symptom of lock-in into unsustainable production and consumption' and conceptualised as "surplus-to-waste lock-in". Within the available data set Paper Two is mainly based on findings related to interview questions 2, 3, 4 and 5, which address causes of overproduction, surplus and waste within the specific industry organisations of the research participants.

Graphic Abstract and Highlights

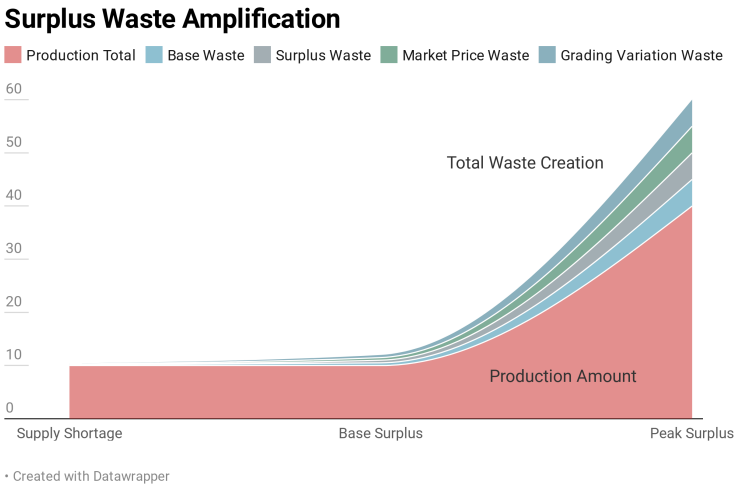

Figure 6: Surplus-to-waste amplification

(*The graphics illustrate conceptual relationships and do not represent research data*)

Highlights:

- Australian horticulture supply chain practices and characteristics encourage production of surplus in excess of demand, while lacking mechanisms for food waste prevention
- Food waste creation is reinforced by powerful lock-in mechanisms that both rely on surplus and resist reducing surplus
- Systemic food waste prevention must target the processes of food waste creation along the entire supply chain
- Transparent monitoring and disclosure of surplus in food chains is an essential prerequisite of food waste prevention

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From surplus-to-waste: A study of systemic overproduction, surplus and food waste in horticultural supply chains

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ABSTRACT

Until recently, food waste prevention intervention has largely offered 'end of pipe solutions' that focus on causes of food waste at specific points in supply chains and on dealing with the physical waste material itself. Recent research has taken a different approach by emphasizing the systemic nature of the food waste problem and the need for its in-depth exploration. This paper offers a systems-based understanding of food waste, which allows for an account of the interconnected processes that underpin waste creation along the whole supply chain. Through a qualitative inquiry on practices and processes of surplus and waste creation in the Australian horticulture industry, the research findings precisely delineate 'surplus-to-waste lock-ins'. That is, the institutional, cultural, and material factors that enable the creation of food waste through the related categories of over-production and surplus formation. The article's identification and analysis of surplus-to-waste lock-ins is grounded in a socio-technical transitions perspective and extends transition studies to agrifood systems and horticultural food waste. This research positions systemic food waste theoretically as a symptom of 'system-lock-in', which may thwart efforts to prevent food waste, and thus bridges micro and macro levels of analysis. These findings translate into three key recommendations for industry, policy and research: that approaches addressing systemic processes of waste creation are essential to unlocking food waste prevention, that food waste prevention should target the identified system processes contributing to food chain lock-ins, and that transparent monitoring and disclosure of food surplus is a prerequisite for systemic food waste prevention across the whole supply chain.

1. Introduction

Global food wastage is a significant challenge for progressively realising sustainable development objectives like world food security. Global food production is resource intensive. It contributes an estimated 19–29% to greenhouse gas (GHG) emissions worldwide (Vermeulen et al., 2012) and accounts for 70% of global fresh water use (Lemaire and Limbourg, 2019). Yet, depending on the measurement protocol deployed, 30–80% of food mass and nutrition value are discarded globally (Alexander et al., 2017; Corrado et al., 2019; Vulcano and Ciccarese, 2017). Such significant levels of waste are problematic due to the threats posed by resource degradation and climate change and considering the distributional inequities that underlie food insecurity currently (Kummu et al., 2012; Springmann et al., 2018). Accordingly, UN member states have agreed to the target of halving per capita food waste by 2030 as part of the Sustainable Development Goals (FAO, 2019).

As a multi-faceted sustainability challenge, food waste has become the latest food-related issue to undergo a conceptual shift from a problem at discrete points of supply chains to a problem embedded within food system dynamics. Accordingly, research has begun framing food waste as the result of complex, non-linear interactions within food chains shaped by broader food systems rather than as an outcome of individual behavior (Göbel et al., 2015, p.1429; Redlingshöfer et al., 2020, p.8). Consistent with systems thinking, this strand of research within food waste scholarship focuses on the fundamental causes of waste rather than dealing

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with the waste material once it exists.

A growing body of research from natural scientists, who employ varying methods for quantifying food waste, reveal 'food overproduction' and 'food surplus' to be significant factors in food waste generation at a global level and in economically developed countries (Hall et al., 2009; Hic et al., 2016). Hence, scholars developing systemic understandings of food waste have emphasized the importance of further research on the surplus-waste nexus (Chaboud and Daviron, 2017; Messner et al., 2020; Mourad, 2016; Papargyropoulou et al., 2014; Pedersen et al., 2015; Vulcano and Ciccarese, 2017). Few studies have explored and explained how and why overproduction, surplus and waste exist and interrelate in real-world contexts, and how they are driven by underlying system settings. One exception is a study by Kuokkanen et al. (2017) that explored the relation between agricultural policy and system processes locking food chains into unsustainable production practices.

This research seeks to advance systemic understandings of food waste by providing an in-depth description and explanation of the food chain dynamics that connect and enable over-production, surplus and waste. Specifically, two research questions guide this study: 'What are the causes of overproduction and food waste at the production stage of the Australian horticulture supply chain'? and 'How does overproduction contribute to food waste along the Australian horticulture supply chain?' In pursuit of these answers, data were collected from twenty-nine supply chain actors through a series of face-to-face interviews conducted in the Australian horticulture industry between 2018 and 2019.

In this paper, the food chain dynamics that connect and enable overproduction, surplus and waste are referred to as 'surplus-to-waste lock-ins' to identify and organize the various interactions that connect surplus to waste along the supply chain. An understanding of 'surplus-to-waste lock ins' is developed through the theoretical lens of socio-technical transitions theory, which is used here to advance systemic understandings of food waste. Specifically, socio-technical lock-in - which represents the aspects and interrelationships that reinforce and 'stabilize (unsustainable) systems'- provides an analytical frame that helps render visible 'blockages' in the food system that thwart efforts to prevent food waste (Geels, 2011, p.25). At the same time, the paper contributes to transition studies by exploring the "specific mechanisms through which lock-in becomes manifested" as well as specific aspects of "regime persistence and preconditions for the development of transition pathways" (Klitkou et al., 2015, p.23). As such, this paper conceptualizes food waste as a symptom of lock-in and food system resistance, thereby advancing and strengthening the empirical and conceptual basis of the systemic perspective of food waste.

Having broadly situated the research problem of food waste within a systems context, the following section unpacks and problematizes the three key concepts: overproduction, surplus and waste. The literature on food systems and food waste is then examined, identifying a key gap regarding the complex 'mechanisms' that frustrate efforts to reduce food waste. Next, the concept of 'lock-ins' from socio-technical transition studies is introduced as a theoretical frame through which to apprehend and understand systemic surplus and food waste and its broader significance beyond horticulture and beyond the Australian case study. This is followed by the methodology section, which outlines the qualitative research methodology with its empirical basis of data generated from semi-structured interviews across multiple sectors of Australian horticulture. The findings section brings forth the voices of horticultural actors that experience the day-to-day practices of the sector in context of broader supply chain operations. This section is organized into the four key emergent themes: a) industry characteristics that contribute to food waste; b) industry practices that encourage formation of surplus; c) the failings of surplus recovery from waste; and d) surplus as an amplifier of waste creation. To finish, the discussion and conclusion sections cement the structural nature of overproduction beyond on-farm decision-makers, which leads to recommendations to navigate these structural constraints via measures addressing the specific lock-in points in research, policy and practice.

2. Literature and background

2.1. Systemic overproduction, surplus and waste

As stated in the Introduction, system approaches to food waste prevention are under-developed in food waste scholarship. Until recently, the literature across the natural sciences had a tendency to focus on 'end of pipe' solutions, including the recovery of value from food surplus and waste, re-distribution, recycling or valorization (Garrone et al., 2016; Kirchherr et al., 2017; Raak et al., 2017; Zaman, 2015). Similarly, the social sciences, with a few exceptions, largely addressed food waste from a 'consumer behavior' standpoint (Aschemann-Witzel et al., 2015; Principato, 2018; Schanes et al., 2018; Stancu et al., 2016). With these bodies of work contributing to understandings of 'what to do' with existing food waste, there are fewer holistic approaches that focus on how to 'prevent waste before it occurs'. Shifting the focus to a 'front of pipe' approach broadens understandings toward a whole of system perspective which examines food waste as embedded in, and as an outcome of, complex, non-linear production and consumption dynamics (Göbel et al., 2015; Mourad, 2015; Redlingshöfer et al., 2020; Thyberg and Tonjes, 2016; Urrutia et al., 2019). Inevitably, this enrolls broader dynamics into the analysis, including the role of policy, politics, economy, markets and institutions, which act as levers in the creation of food waste. As such, a food systems approach is central to unlocking the interrelated dynamics that produce large volumes of horticultural waste across the supply chain.

'Food systems' offers a conceptual framework that provides a non-linear understanding of interactions across food supply chains. It encompasses the outcomes of these interactions, and the ways feedback loops, outcomes and external factors influence how food systems, including food chains, function (Ingram et al., 2013). Accordingly, 'food systems' has become the predominant way to conceptualize food-related issues and interventions to address them (Ericksen, 2008). Food waste, despite gaining increased attention as a major environmental and social challenge, has only been a 'marginal' concern of food system studies and only minimal research on the significance of food waste in food systems is currently available (Hodgins and Parizeau, 2020, p.43). Halloran et al. (2014, p.295), for instance, have called for "systemic evidence" of the detailed linkages between food system design, operation and food waste as an outcome. Bengtsson et al. (2018, p.1542) have encouraged research to elaborate "what factors leave food systems prone to producing large amounts of surplus/discarded food", while Redlingshöfer et al. (2020, p.9) suggested that future research should "focus much more on the drivers and determinants of food waste generation in all food system sectors". Other research has highlighted the need for deeper analysis of systemic food waste (Vulcano and Ciccarese, 2017, p.46), including its "decision processes and actors" (O'Rourke and Lollo, 2015, p.242) as well as relevant "relationships and automatisms in the food chain" (Göbel et al., 2015, p.1441).

Relative to consumer-focused studies, a small body of recent work within the interdisciplinary field of food waste research positions 'overproduction' as a fundamental characteristic of food systems that, in combination with other factors, leads to food surplus that turns to waste (Chaboud and Daviron, 2017; Mourad,

2016; Pedersen et al., 2015; Vulcano and Ciccarese, 2017). Research from environmental science has shown that overproduction contributes to the gap between production and consumption that gives rise to food surplus throughout a supply chain (Hic et al., 2016, p.4270; Papargyropoulou et al., 2014, p.112). Findings that the food production stage, i.e. farm waste, is disproportionately responsible for food surplus and waste support a focus on production as a key point where the structure of food chains promote food surplus creation (Alexander et al., 2017; Johnson et al., 2018; Porter et al., 2018; Raak et al., 2017; Vulcano and Ciccarese, 2017). As understandings of food waste as a systemic phenomenon have emerged, multiple gaps in knowledge about overproduction, surplus and waste generation in primary production have been revealed. There have been calls for further research on farm waste generation (Beausang et al., 2017; Redlingshöfer et al., 2017), especially studies that cover a range of multiple crops (Hartikainen et al., 2018), and address unrecorded and unclassified waste at the pre-harvest stage (Schneider et al., 2019).

Beyond quantification of overproduction and surplus, social scientific work within food waste scholarship has suggested various food systems characteristics that may contribute to overproduction. These causal factors include: a common lack of demand transparency across a complex food supply chain (Calvo-Porral et al., 2016; Halloran et al., 2014; Lemaire and Limbourg, 2019), the emphasis on specialization and industrialization of food commodity chains (Canali et al., 2013; Mourad, 2016), regulatory interventions (or the lack thereof) that have the effect of incentivizing overproduction such as production-oriented subsidies (Bengtsson et al., 2018; Pritchard, 2012), routine encouragement of overconsumption (Banwell and Dixon, 2013; Friel et al., 2014) and exercises of supermarket power over suppliers (Devin and Richards, 2018; Feedback, 2018; Ghosh and Eriksson, 2019). Kuokkanen et al. (2017) have applied a socio-technical perspective to identify underlying system processes that have been locking Finnish food systems into unsustainable overproduction. They exposed underlying mechanisms of overproduction that reinforce lock-in through their linkages to agronomic intensification and agricultural policy, without placing a central focus on systemic food waste creation. As such, the exact combination of causal factors of overproduction, the inherent mechanisms by which they are linked to food waste outcomes and the potential interventions to address them, are shaping and being shaped by the context of the supply chain and broader food system and require further in-depth research.

Responding to these knowledge gaps, this paper contributes to systems-based understandings of food waste to uncover and explain how systemic practices and processes in the Australian horticultural supply chain give rise to overproduction, surplus and ultimately food waste. The next section of this paper outlines socio-technical transitions theory as a framework for establishing a broader theoretical understanding of the features of complex food systems that both promote, and rely on, systemic overproduction and the creation of waste.

2.2. Socio-technical transitions theory and the dynamics of overproduction

Preventing food waste in a complex system, such as a horticultural supply chain, requires a transition toward more sustainable, or less environmentally destructive, practices (El Bilali, 2019; Hinrichs, 2014; Meynard et al., 2018). Transition studies, and in particular socio-technical transition theory, has emerged as a significant body of work in addressing complex phenomena at the intersection of society and technical systems, referred to as regimes (Murphy, 2015). A socio-technical regime refers to dominant systems with social and technical configurations, such as water, energy, agrifood, housing and transport (Geels, 2010). The various components of a regime include, among other things, a network of actors, technologies, infrastructure, norms and rules (Lachman, 2013). Geels (2010, p.502) argues that incumbent regimes are often stabilized via corporate-driven networks with strong links and interdependencies with policy makers. Radical alternatives to current regime practice, termed 'niches', challenge or disrupt the status quo while various factors, termed lock-ins, counter such change by reinforcing the existing regime (Geels, 2014; Köhler et al., 2019). The ensuing interactions and dynamics give rise to a 'multi-level perspective' of system transitions to sustainability. Sociotechnical transitions theory is useful for conceptualizing the structural nature of overproduction in food chains through its emphasis on: (a) how and why a particular socio-technical system emerges; and (b) the ways in which systems dynamics resist change, but nonetheless transform over time.

The concept of a socio-technical 'lock-in' is especially useful for understanding how food systems and the food chains embedded within them reinforce suboptimal outcomes (in this case, high levels of food waste) and why such outcomes are difficult to resolve (Geels, 2011, 2014; Seto et al., 2016; Unruh, 2000). Lock-ins explain the "efficient convergence of established ways of seeing and doing things" (Svingstedt and Corvellec, 2018, p.5). A 'lock-in analysis', therefore, focuses on the overlapping mechanisms through which a system becomes entrenched and reinforced, and how these mechanisms resist transition to a more sustainable sociotechnical system (Meynard et al., 2018, p.53).

Research has differentiated between distinct types of lock-in mechanisms and their interactions within the incumbent socio-technical regime. These mechanisms may be institutional (e.g. existing legislation and policies), technical (e.g. business models and technologies), cultural (e.g. accepted views and paradigms) and material (e.g. existing infrastructures and investments) (Corvellec et al., 2013; Seto et al., 2016). Lock-ins within complex systems, however, defy such distinct groupings and linear relationships. Accordingly, lock-in analysis of complex systems tends to find "nuanced multi-rational understandings" of different aspects to a system that collectively reinforce the system, rather than distinct lock-in mechanisms unrelated to each other (Svingstedt and Corvellec, 2018, p.5). For these reasons, and as shown later in this paper, lock-in analysis of food systems defies neat categorizations, highlighting complexity of present food chain characteristics and the manifold ways they compound to perpetuate the status quo.

An especially powerful type of institutional lock-in occurs in socio-technical regimes whereby private and public institutions and technologies have co-developed and co-benefited from increased revenue and economic returns over time (Unruh, 2000, p.825). Rather than aiming to check and balance each other's political processes, public regulatory interventions and corporate governance share a common interest of reinforcing the incumbent socio-technical regime, frequently and persistently leading to "market and policy failure" (Unruh, 2000, p.817). Critically, socio-technical regime actors are not seen as institutionally locked-in and inert due to systemic constraints, but as actors that intentionally resist change even if resistance is counter to broader social goals such as sustainable development (Geels, 2014, p.35; Seto et al., 2016, p.433). In agrifood systems, this resistance to change (i.e. lock-in) may come in the form of existing infrastructure design, sunk investments and regulatory standards perpetuating and reinforcing 'business as usual', which in turn contours how the problem of food waste is understood and addressed.

Sustainable transitions, including the reduction or prevention of structural food waste as an unsustainable food system outcome, require "escaping the lock-in conditions" (Unruh, 2002, p.317). By locating specific lock-in points and mechanisms within a socio-

technical regime and rendering them visible, stakeholders can identify and engage in consciously dismantling lock-ins to develop tangible pathways toward sustainable change (Geels, 2014; Svingstedt and Corvellec, 2018). Accordingly, transition research has highlighted the need for further research into the "specific mechanisms through which lock-ins become manifested" (Klitkou et al., 2015, p.23) and studies on whole industries, rather than single cases, that produce transitions (El Bilali, 2019, p.361), both of which this paper contributes to.

Unruh (2002, p.320) added a caveat: breaking such deeply entrenched and intransigent institutional lock-in, stabilized by an alliance of business and political elites, is unlikely to be initiated from within the system itself. Rather, change will likely require an exogenous force, such as an 'external shock'. While lock-in analysis may be able to provide a viable agenda for systems change, such change is ultimately subject to mediation by power and politics. The following section turns to the research methodology to demonstrate how data was gathered to identify lock-ins in horticultural supply chains.

3. Methodology

This study follows the interpretivist epistemological tradition, where the researcher seeks a deep understanding of a phenomenon through the lived experiences of actors closest to the subject matter. In Australia's horticultural supply chain, these are growers, processors, peak body representatives and technical experts. Potential research respondents were identified through a non-probability, purposeful sampling approach targeting a diverse cross section of the Australian horticulture industry to maximize the range of insights and perspectives (Zikmund, 2003). Based on an industry overview of key market segments (IBIS World, 2019), the research covered six relevant sectors of the Australian horticulture supply chain. The sampling strategy ensured participation by growers and initial processors supplying to Australian supermarkets and wholesalers, which are the predominant mass-market channels for fresh fruit and vegetables (Salardini, 2019). Hence, the sample was representative of the market in regard to capturing a range of relevant perspectives.

The method of data collection was a series of recorded semi-structured interviews with people working across the horticultural sector (for example of this method see Cresswell and Poth, 2018). Interviews took place at participants' offices and were conducted face-to-face. Personal interviews with key industry actors are more difficult to obtain than phone or video interviews due to constraints of time, travelling and availability. However, the additional efforts to support a strict-face-to face interview approach were rewarded with increased opportunities for interaction, first-hand observations, and information shared by respondents beyond the interviews themselves. The initial planned sample consisted of 70 respondents with ultimately 29 participating in the research, which represents a response rate of 41%.

As noted above, the research questions guiding this study are: What are the causes of overproduction and food waste at the production stage of the Australian horticultural supply chain? and How does overproduction contribute to food waste along the Australian horticultural supply chain? To address this, an open-ended interview instrument was developed which included general questions and follow-up questions about management practices in regard to food waste, overproduction and surplus within Australian horticulture. Interview questions addressed prevailing practices and priorities in relation to food waste at the production stage. Moreover, questions were aimed at clarifying and identifying practices, constraints and processes relevant to overproduction and the conditions under which surplus produce is discarded on-farm.

The data set consisted of 28 recorded and transcribed interview sessions (see Table 1) comprising almost 20 hours of interviews. Data analysis was informed by "adaptive theory" (Layder, 2006, 2018), a research methodology that explains social phenomena by connecting human activity to social structures (Van Gramberg, 2006). Specifically, adaptive theory draws on the explanatory framework of 'social domains', which proposes a multilayered social reality of immediate and personal domains, such as 'psycho-biography' and 'situated activity', as well as remote and structural dimensions, such as 'social settings' and 'contextual resources' (Carter and Sealey, 2000). This means that data analysis followed a procedure of thematic coding including life world phenomena emerging from the data as well as theoretical codes related to social domains. Emerging themes and concepts are thus constituted by descriptive as well as conceptual elements. This is followed by an interpretation and causal explanation of data based on underlying social domains and their specific capacity to transform social reality (Hewege and Perera, 2013; Layder, 2018). The research findings were thus able to establish and explain system phenomena based on inferences from causal sequences, mechanisms and relationships, an approach called "explanatory causality" (Shadish, 2010, p.9; also see Grin et al., 2010, p.97; Layder, 2018, p.42).

The research findings reported below purposefully focus on the voices of growers in recognition of the value of first-hand experience with food surplus creation that turns to waste.

4. Research findings: food surplus production and food waste

This section reports the key findings from the research interviews in relation to four systems phenomena. The findings are reported in narrative style recounting the underlying layers and networks of empirical data and concept indicators to highlight the specific points where systemic overproduction lock-ins and waste creation occur. This section presents the findings, with the first two themes addressing Research Question One on causes of overproduction and food waste, and the second two themes relating to Research Question Two on the relationships between overproduction, surplus and food waste. The theoretical interpretation of findings will be explored in the discussion section further below.

4.1. Industry characteristics that contribute to food waste

An industry peak body representative from Melbourne proposed the expression of "growers boxed into a corner" to capture the growers' perceived transition from power as the nation's 'backbone' to a minor actor facing numerous constraints within a complex marketplace. Now, market actors and institutions profoundly shape farm management decisions, in turn constraining the growers' ability to determine fully how much is grown, what is grown and how it is grown. An important point to understand is that "growing vegetables is a business, farmers do it for money", as a Queensland vegetable grower explained. A Victorian grower similarly stated that, "Our sole form of income is what we sell. There's no other magic fountain". Growing food for a living is thus predominantly determined by the conditions of commercial reality.

The position of growers is epitomized in their repeated description of themselves as 'price takers' not 'price setters'. One South East Queensland vegetable grower explained how the lost connection to consumers relates to lost price power: "We have done one thing very poorly for a very long time, we left it to retailers to tell our story. Now, [the consumers] run away and say: you are on your own!" In the highly concentrated and oversupplied Australian trade environment, the oligopolistic position of supermarkets has been determining the prevailing agri-business model in which growers have to compete. The interviews frequently

Table 1
Overview of research participants.

Ref.	Position	Organisation	Industry	Length (mins.)	Location
01	Technical Manager	Industry Association	FRUIT	39:00	Brisbane
02a	Owner*	Grower	VEG	55:00	South East Queensland
02b	Owner*	Grower	VEG	55:00	South East Queensland
03	Managing Director	Grower/Wholesale/Agent/Distributor	WHS/FRUIT	30:47	Brisbane
04	Managing Director	Wholesale/Agent/Distributor	WHS/FRUIT	49:04	Brisbane
05	Owner/Industry Representative	Grower/Industry Association	FRUIT	47:48	South East Queensland
06	Owner/CEO	Grower/Industry Association	FRUIT	47:47	Brisbane
07	Owner/Executive Officer	Grower/Industry Association	FRUIT	56:48	South East Queensland
08	Business Manager	Grower/Wholesale/Agent/Distributor	VEG	56:13	South East Queensland
09	Owner/Industry Representative	Grower/Peak Industry Body	VEG	*55:00*	South East Queensland
10	Technical Director	Grower	FRUIT	38:47	South East Queensland
11	Technical Manager	Peak Industry Body	FRUIT/VEG	39:30	Melbourne
12	Director	Wholesale/Agent/Distributor	WHS	40:59	Melbourne
13	Technical Manager	Industry Association	FRUIT	37:49	Melbourne
14	Industry Manager	Peak Industry Body	FRUIT/VEG	39:16	Melbourne
15	Owner	Grower	VEG	38:16	South East Victoria
16	Director	Grower	VEG	46:40	South East Queensland
17	Technical Manager	Peak Industry Body	FRUIT/VEG	40:26	South East Queensland
18	Food Supply Manager	Other Industry Services	OTHER	20:35	Brisbane
19	Owner/Industry Representative	Grower/Peak Industry Body	VEG	41:04	South East Queensland
20	General Manager	Other Industry Services	OTHER	44:31	South East Queensland
21	Production Manager	Grower	VEG	37:31	South East Victoria
22	Owner	Wholesale/Agent/Distributor	WHS	34:32	Melbourne
23	Senior Officer	Peak Industry Body	FRUIT/VEG	39:11	Brisbane
24	Owner/CEO	Grower/Industry Association	FRUIT	38:01	Northern Rivers
25	Director	Wholesale/Agent/Distributor	WHS	42:24	Brisbane
26	Managing Director	Grower	VEG	32:23	South East Queensland
27	Owner/Director	Grower/Wholesale/Agent/Distributor	FRUIT	44:50	South East Queensland
28	Director	Other Industry Services	OTHER	37:31	South East Queensland

* Interview session 2 combined two growers in one session.

describe how supermarkets control market access as almost no viable alternative mass distribution channels exist. Crucially, supermarkets are also the primary interface between producers and the consumer market, which further limits market access for growers and creates information and power asymmetries. This privileged position in the supply chain allows supermarkets to design their business model around exclusively selling what they define as premium grade product purchased at lowest available cost, causing large amounts of produce considered outside of the supermarket definitions to go to waste.

Research participants commonly described the implementation of supermarket specifications and cosmetic standards as an example of their disempowered position. There was wide awareness and belief among research participants of the very substantial scale of on-farm food waste due to supermarket standards, some estimates ranging from 20% to 50% of production. Cosmetic standards are a matter of definitions, which predominantly relate to size, shape and color of produce and not eating qualities such as taste and nutrition. Respondents commonly expressed disbelief that supermarket standards reflect *real* consumer preferences. On the contrary, supermarkets were seen as deploying marketing practices that respondents described as 'conditioning', 'education', 'training' and 'manipulation' to instill and establish expectations of what 'perfect fruit' look like. Moreover, some respondents reported having observed the unfair use of supermarket standards as a negotiation tool to downgrade price or to control market access.

Ensuring the cosmetic appeal of fruit and vegetables has, therefore, become a priority in the Australian horticulture industry. Some participants regret the lack of a 'cohesive industry approach' that 'speaks on behalf of what's best for all farmers and takes a long view' on farm waste rather than fulfilling the demands of supermarkets. Other participants believe it is government leadership that is needed to change the prevailing agri-business model in regard to supermarket standards. "It sits very much on the shoulders of the government. They are the policy makers, their decisions have a ripple effect, particularly for small growers", as a Melbourne distributor observed. However, government regulation is seen as unlikely since Australia is firmly committed to liberalized agricultural trade. As government and industry advocate self-reliance in an 'open market', respondents were clearly aware that the waste problem is essentially up to the individual grower.

In the absence of citizen/consumer support as well as industry action or government regulation to address waste due to cosmetic supermarket standards, it has become an important 'business skill' of growers to pre-empt how supermarkets will apply their standards. Some vegetable growers reported that they do this by abandoning the imperfect crop in the field rather than paying for the crop to be harvested only to be rejected. In the absence of a physical waste stream to be moved to waste transfer stations, the practice of on-farm waste disposal is widely seen as *natural* and quite a number of growers did not consider grading rejects left in the field as food waste at all. One vegetable grower explained, "We have no problem with waste, it will return to the soil as nutrition". Another grower added, "It is food for the next crop". Not all growers agreed on waste as 'natural' as some respondents recognized the financial, personal and resource-related inputs lost in the process. Moreover, a waste management expert pointed out that on-farm disposal without a true composting process represents at best a 'suboptimal resource use', motivated by disposal rather than an approach to improving soil health.

Despite its very substantial scale, grading waste remains 'intentionally unseen' and 'excused', as a Brisbane distributor remarked. Respondents suggested there is some amount of conditioning inherent in the acceptance of farm waste as natural; "I think it's psychological because the big end of town tells [the growers] that produce has to be perfect, that it is what the people want. And that comes directly from supermarkets". Inherent in these critiques is the assumption that, within the prevailing governance

arrangements of the Australian food supply chain, only supermarkets themselves can reduce the number of unharvested crops that go to waste on-farms.

4.2. Industry practices that encourage surplus formation

The strong majority of informants concurred that overproduction and resulting surplus was a highly prevalent feature in the Australian horticulture industry. One grower and processor stated, "[Surplus] is huge and it's being wasted". Others agreed, there is "overproduction in vegetables" and "domestically and even worse in the export market". One industry sustainability manager summed up the matter most concisely; "'They [growers] all grow too much!'. With the existence of overproduction and surplus thus confirmed, the respondents from the horticultural industry offered further deep insights into the dominant processes that generate surplus.

From interviews with actors in the horticultural sector, it is clear that overproducing is considered a standard practice in the industry. A South East Queensland vegetable grower declared that "'Everybody does it". The most common reason for overproducing is to hedge against risks related to weather events, the timing of growing cycles, or changes in domestic or export market conditions. Interviewees also spoke of a tendency inherent in the industry to 'gamble' on potential commercial opportunities, which requires being 'always ready to sell when others cannot'. Moreover, growers are very strongly 'connected to productivity' and have a deeply entrenched belief that 'yields must be maximized as they are the key to profitability'. A number of growers summed up the prevailing sentiment that 'growing more is always better'.

Food surpluses caused confusion for stakeholders as their existence conflicts with mainstream policy narratives that emphasize projections about how much food production is needed to feed future populations. As one actor put it, "We have got oversupply and then we've got to double food production, I don't know how to mill these two together in Australia". Similarly, another horticulture industry representative considered surplus as a supply demand conundrum: "Consumption per capita is decreasing but we are generally going up in production". The output of Australian agriculture in key sectors has been exceeding the demand of domestic markets for many years, and respondents are aware that productivity growth has been outpacing population growth. Still, government and industry organizations strongly emphasize further growth and further productivity increases as a top policy priority across various platforms. A sustainability extension manager explained how growing and governing might be critically at odds: "The government says we need 40 percent more product. Well if [supermarkets] actually reviewed their product specs, the 40 percent is sitting there, on-farm now, you wouldn't have to grow anymore". A technical farm manager added, "The 40 percent is probably being produced already, it's just not being utilized".

Because of the persistent pressures to increase productivity, growers described being in a debt spiral, that is, ever-increasing levels of debt, due to the convergence of rising input costs, stagnating market prices and the continuous need for investments into more growth and productivity. The resulting financial squeeze of low profit margins and high debt translates into pressures to produce cash flow and to keep growing, with or without profit. One vegetable grower from the Lockyer Valley, Queensland, summarized the commercial reality of the need to continuously grow more: "The industry is set up now so we have to overproduce. There is no margin to grow less".

Pressure to overproduce also derives from competition in a highly concentrated and oversupplied marketplace, which, as a Queensland technical manager explained, "Has in itself ways to encourage oversupply". Australian growers seeking access to mass markets have no option but to invest into securing supply contracts with major supermarkets, which represent by far the most dominant route to market. To safeguard their continued relationships with supermarkets, growers must be ready to fill orders around the year, irrespective of profit or loss. The key objective is never to be short in supply, as that would open a window for a competitor creating a lost opportunity and potentially weaken vital supply relationships. One grower explained, "If I can't supply, someone else will – cheaper!", which makes "undersupplying a very bad business".

To succeed in competition, respondents spoke about specializing in growing a narrow range of crops intensively to exploit economies of scale. This in turn increases the market supply of particular fruit and vegetables while increasing the exposure of crops to external factors like pests and diseases. Growers also work towards narrow windows of profit opportunity within the growing season for the crop they specialized in, and they accept narrow profit margins in order to meet the lowest market price. All these factors combined mean growers gamble to remain competitive. A vegetable distributor explained that winning or losing the gamble of narrow margins, for instance, ends with some growers reaching market with their production output while others get saddled with sizeable surpluses. The risks taken to remain competitive are especially high due to the lack of transparency and information around demand. Aggregated and accessible data on real market demand are presently not available to producers from within the supply chain, which leaves growers no option but to follow the cues of supermarket buyers or try to 'listen to the market and look over the fence', at times asking themselves, as one Queensland vegetable grower said, "Are we in a safe place if we don't overproduce?"

Several growers see surplus mostly related to the business model chosen by producers. Some businesses supplying the mass market have transitioned to an operational model that prioritizes steady and stable supply patterns over betting on large yields of produce. Such growers manage their business based on pre-orders and producing to demand. They generally reported only negligible surplus and waste and stable operating margins. The majority of growers, however, being fully invested in the race of intensive growth and larger yields, have to keep producing more at lower cost to make ends meet, which they do by simply 'producing the maximum they can'.

4.3. The failings of surplus recovery from waste

Once surplus has formed its physical presence on farms, growers face the immediate pressure of managing an oversupplied perishable crop, within a narrow timeframe and location, and as market prices rapidly decline. The key priority of management is minimizing economic loss either by way of maximizing cost-recovery or cost-effective disposal. Some of the evidence provided by this research indicates the current supply chain infrastructure appears inadequate in its support for either goal.

During times of temporary oversupply such as gluts or peak season, supermarkets and central wholesale markets will work with growers to 'sell through' and digest some of the excess produce, mostly via price reductions and push promotions.[1] Those channels represent almost the entire market available to growers. As a Melbourne based distributor explained, "Growers have no alternative mechanisms to sell surplus product in large quantities". As there is finite demand for surplus produce and natural limits for

[1] Promotions pushing product down the supply chain by inducing shoppers to increase purchase, e.g. price discounts, coupons, or promotion packs.

price reductions, the common result is that large amounts of surplus produce remains unsold on-farm. A number of interviewees described how, almost without exception, food surplus thus created is discarded on the farm itself, as transportation cost, especially in light of narrow profit margins, makes it uneconomical to move it to processors or transfer stations. Growers generally plough food surpluses back into the soil, while waste already harvested is often left in piles, fed to livestock or put out onto the field as 'compost'.

Some growers considered export channels to dispose of surplus, mostly by selling to export agents. Yet, export markets require strategic investment into export readiness, into compliance with import protocols and into demand creation in destination markets. Some representatives of industries with export business explained how it is not simple and straightforward to move rapidly from supplying domestic supermarkets to export. Importers have specific service requirements (e.g. for packaging and certification) and need long-term stable service, which presents its own challenges to producers. As such, some respondents cautioned against considering export markets as 'dumping grounds for surplus'. A vegetable grower also observed that export markets are also commonly subject to oversupply due to similar competition dynamics that lead to oversupply domestically; hence the existence of export markets may, to an extent, even compound the processes that cause surplus and waste.

In recent years, processing and value-adding has increasingly gained popularity as a potential avenue to dispose of surplus without producing less. In principle, growers, or other supply chain actors, can process surplus or even waste into new products, for example, guacamole, banana flour or neutraceuticals. However, the research participants described multiple difficulties with putting the concept into practice on a larger scale. On-farm value-adding requires significant investments into equipment and working capital. As an alternative, some respondents with a processing background explained, surplus can be delivered to third-party processors, which reduces investment and risk. However, they added that produce has to be competitive in meeting the processor's sourcing requirements, such as transportation cost, timeliness for perishable products, product characteristics, product hygiene and traceability, and supply stability, all of which might drive up the cost of diverting surplus to processors and make it more economical for processors to grow their own produce, rather than using surplus from around the country.

Indeed, research participants viewed value-adding as representing an entirely new skillset, even a 'whole new supply chain' with substantial investments required into product development, branding, registration, distribution, and demand creation within the very same market channels that were unable to absorb the surplus in the first place. Accordingly, for growers to transition towards value-adding to surplus food and innovative use of the waste resource, they must be prepared to make significant changes, from infrastructure through to knowledge. Moreover, the value-added products will have to compete in an Australian processing industry that has been forced into steady decline due to high operating cost and international low price competition, making it likely that value-adding itself will create new waste chains. Considering existing pressures, growers are not commonly able to take such risks and make such investments.

Growers also mentioned some other options to redistribute surplus product rather than disposing it on-farm. These include donations to food rescue organizations, sales to local fruit and vegetable markets, on-farm sales and local diversion to stock feed. However, respondents noted that the especially high levels of surplus and the lack of alternate distribution channels beyond mass consumer markets severely limit re-purposing of food surpluses. The failure to regain value from surplus hastens its transition to food waste, which the next section explores further.

4.4. Surplus as an amplifier of waste creation

The in-depth analysis revealed system mechanisms that showed how surplus engenders and accelerates the creation of waste. Surplus thus emerges not only as a contributing cause of waste, but as an amplifier of existing causes of waste creation. Three mechanisms of waste amplification emerged from the research data:

4.4.1. Surplus increases the rate of waste

Interview data revealed that industry practices, such as cosmetic standards, cause food waste even in the absence of significant overproduction and surplus. As a technical director from Brisbane explained, "Once surplus is removed, the problem of supermarket standards and specifications is still there", which leads to a "certain amount of waste due to a basic grading reject rate of about 20% every day". One vegetable grower pinpointed the impact of surplus on waste generation: "There is always a percentage of base waste, but a lot more with excessive numbers".

Overproduction causes large surplus during gluts and peak season, boosting harvest quantities and corresponding surplus and waste volumes. One technical farm manager explained, "Peak season harvest amounts could reach four times the normal harvest, potentially causing four times the amount of waste". Moreover, growers described how field and shed waste do not only increase *in line* with harvest volume, but potentially at an *increased rate* of rejects and discards due to harvesting processes running closer to the limits of their operational handling capacity and the need to move large influxes of highly perishable produce to market within much shorter time-frames. For example, during peak, surplus grading has to be faster and broader to cope with staggered plantings coming into harvest quickly and simultaneously. A Victorian grower explained how they accelerate grading during peak season: "We generally pick [a patch] two or three times, but if the next patch is ready, we'll leave the old ones and we'll just go and pick the next ones, and then we'll just mulch it into the soil". As such, peak season harvest practices contribute to increased rates of waste creation.

4.4.2. Declining prices increase waste

From a producer's perspective, market prices heavily impact on whether a crop goes to harvest or to surplus and waste. Low prices mean the costs of growing and harvesting surplus may not be recoverable at the given or rapidly declining market price point; conversely, harvesting might result in growers operating at a loss. Because oversupplying is an engrained feature of how growers conduct farming, 'price depletion', as an industry representative called it, has become a corresponding characteristic leading to continuously diminishing profit margins for growers already operating on very narrow margins. Crops under sustained oversupply and depleted margins are more sensitive to downwards market price trends and may fall below thresholds of financial viability faster than more profitable crops. Thus, the overproduction of these crops, which drives, and is also encouraged by, the downward market price trends, contributes disproportionately to waste.

Some respondents described how promotional activities to sell-through surplus are commonly used to mitigate the amount of surplus that goes to waste as market prices decline. However, growers realise that promotions are a limited means of preventing surplus turning to waste. These limitations include the short amount of time to sell due to perishability, the decreasing financial returns as produce ages and the consumers' finite ability to digest

surplus product. Ultimately, surplus meets what a Victorian grower called 'market resistance', when "You can't move product any longer". A fruit industry representative summed it up by saying, "Once the harvest is economically not viable, it is the financially responsible thing to do, not to pick and instead to have food waste".

4.4.3. Changing standards increase waste

An oversupplied market is a buyer's market, which in Australia is primarily two major supermarkets. A number of interviews highlighted how during supply shortages, supermarkets may buy produce that is not fully compliant with their specifications. A Queensland vegetable distributor stated, "[The supermarkets] will give us a degree of flexibility if they are in short supply, to get some product on the shelves". Consequently, waste generation is much reduced or even ceases altogether during supply shortages. During peak supply, however, waste becomes prevalent as the oversupplied market offers abundant choice to supermarkets. This allows supermarkets to strictly apply their specifications and deny any 'standard variations', as some respondents called the flexibility sometimes granted by supermarkets, thereby effectively driving up wastage rates. During this period, for instance, the oversupply of premium produce often leads to produce in lesser grades turning into waste, further contributing to trade-related waste on-farm and in pack-houses. A technical farm manager observed, "There is no outlet for seconds during peak season. Stuff that would normally get packed in 'second class' will just get dumped".

5. Discussion

Research participants revealed a strong connection between overproduction on-farm leading to surplus that turns into waste within Australian horticultural supply chains. In respect of Research Question One, fundamental characteristics of the broader supply chain, such as the relationship between growers and the supermarkets, reveal the structural nature of overproduction and farm waste creation beyond on-farm decision-makers. Meanwhile, responding to Research Question Two, a large amount of surplus actually stays on the farm and turns to waste due to the lack of infrastructure enabling its beneficial use. As such, much of the burden associated with the food waste generated affects growers more than other supply chain actors. To explore these characteristics further, and by drawing on the well-recognized concept of lock-ins from socio-technical transitions theory, this discussion section brings together the literature, theory and data to expose the 'surplus-to-waste lock-in' mechanisms that reinforce systemic overproduction leading to surplus and waste in the Australian food supply chain. This study identifies three key overlapping lock-ins, which were introduced in the section on socio-technical theory (see 2.2) and which are explored below under the following headings: institutional, cultural and technical-material lock-ins.

5.1. Institutional lock-ins

The data provides insights relating to institutional lock-ins in the food system. The interests of supermarkets, industry representatives and government converge to govern food in ways that reinforce retail market concentration and growth and productivity maximization. Specifically, the growers' practices within the food supply chain were profoundly shaped by their relationships with superior and dominant forces in the supply chain, by the lack of regulatory counterbalance and by a systemic disconnectedness from consumers. These findings are consistent with the fact that Australian horticulture is predominantly comprised of intensive, specialized agriculture and highly centralized supermarket distribution infrastructures (Bjørkhaug and Richards, 2008). This dominant food chain for fruit and vegetables is supported by Australia's low regulatory intervention into agricultural markets (Larder et al., 2017) that strongly favors incumbent industry networks. Meanwhile, overproduction is normalized via the political-economic focus on growth and productivity (Lawrence et al., 2012). For instance, the industry and government vision is to almost double output of an already oversupplied industry (NFF, 2018). Consequently, government and industry bodies prefer to leave the waste problem to individual growers, in a similar way to how food waste responsibility is shifted to individual consumers.

This institutional lock-in mechanism also relates to the powerful regulatory role of supermarkets. The research reveals that growers have been increasingly facing institutional and regulatory pressure from private governance mechanisms, especially supermarket standards, rather than government regulation. As such, regulation of standards devolved from government to supermarkets, reinforcing the status quo that favors prevailing interests (Seto et al., 2016). Findings illustrate that the supermarkets model, which relies on stable and centralized supplies, supports the reported inconsistent implementation of their standards and specifications. By having large supplies to choose from, and strong contractual rights and "institutional power to impose specific standards", supermarkets can exclusively sell fruit and vegetables that look a particular way (Klitkou et al., 2015, p.34). While overproduction to satisfy the interests and standards of supermarkets reinforces itself by depressing the prices for a particular fruit or vegetable, farmers continue to pursue profit by producing more food and so become locked-in to investments into technologies and infrastructure for maximizing production, which debt in turn keeps them trying to produce more food surplus. These dynamics feed the systemic need for overproduction, while the share of the benefits "depends on one's institutional perspective" (Seto et al., 2016, p.437). Because supermarkets are the main buyers, there are not only few alternative channels to distribute product, but also the actual demand from consumers is obscured. In other words, oversupply in a concentrated marketplace obscures and distorts real market demand and leaves growers no direction but always to produce the maximum.

The power of supermarkets in Australia is indicative of deep seated institutional-technical lock-in resulting from a form of governance which presumes industry and markets will self-regulate (Richards et al., 2012, p.252; Unruh, 2000, p.824). Rather, Australia's relatively weak competition laws and comprehensive industry de-regulation have allowed supermarkets to accrue disproportionate power compared to other supply chain actors. The institutional lock-in occurs when Australian governments refrain from regulating supermarket standards, but also from the pivotal role private supermarket governance has assumed in regulating the Australian food industry (Carey et al., 2017). As such, the state reliance on private actors to set and enforce standards serves to further exacerbate institutional lock-in and transition resistance.

5.2. Cultural lock-ins

A second, and closely related, lock-in mechanism in favor of overproduction relates to the cultural understandings of 'what fruit and vegetables should look like' that in turn influences production and consumption decisions. The research reveals a deep cultural lock-in related to the cognitive conditioning in regard to imperfect-looking produce and its associated waste. Research participants firmly believe that consumer perceptions and expectations on perfect produce are socially constructed. Specifically, they believe consumer standards have been created through long-term 'manipulation', and 'conditioning', by dint of commercial marketing practices. Equally, growers have developed a 'business skill' to

proactively discard any produce that will likely be rejected by the trade, as well as an acceptance of 'financial responsibility' to prevent economic waste by discarding produce on-farm as food waste.

Correspondingly, the resulting on-farm waste is often not regarded as waste at all, but rather as nutrients being returned to the soil. This concept of waste as 'natural' and as something that helps soil health reveals a deep cognitive dissonance between growers' acute awareness of waste as a real economic loss and a real loss of resources, and their acquiescence to waste as a natural part of doing business. Existing cultural and cognitive conditioning regarding the perceptions of imperfect produce, combined with the growers' interpretation of food surplus going to waste as 'natural', correspond with the high levels of food waste generated at the production and initial processing stages (Australian Government, 2019), revealing a deep-seated lock-in into waste from production and consumption related cultural dynamics.

5.3. Technical-material lock-ins

A final lock-in mechanism derives from the prevailing agribusiness model and the associated material infrastructure, practices and processes in place. Transition research has shown how "business models can constitute a hindrance to change" (Svingstedt and Corvellec, 2018, p.6). This paper has elaborated two important dynamics of the horticulture food chain model. Firstly, it described the journey of food from the field, via surplus to its final destination as food waste. The research findings have revealed the deep relationships between surplus and waste and the underlying mechanisms that support and enable this connection. Secondly, the research findings also emphasized the systemic nature of this transition. They described the specific industry settings and characteristics that determine what and how much is grown, the processes and dominant practices that necessitate and reinforce overproduction, and the specific material and ideological resources that represent an industry infrastructure supporting surplus production but inadequate for surplus and waste prevention.

Horticulture supply chain processes and their governance encourage structural overproduction and food surplus formation. This means existing supply chains, for instance, due to the deeply engrained systemic focus on yield, are inherently ill-suited to sustainable change, such as reducing food waste (Ferguson, 2016). Rather, the very processes causing surplus to form in the first place also facilitate and expedite its transition to waste. Once surplus has formed, price reductions and promotions erode market prices leading to supermarkets asserting their power by raising standards to reject increasing amounts of produce that will not sell. The research has shown substantial management constraints related to overcoming the 'waste miles' of perishable surplus produce to ensure its meaningful re-use and to prevent its transformation to waste; these are the lack of adequate infrastructure to manage surplus, the ambiguous economic value of 'waste as a resource' and the absence of relevant industry and policy priority. The research findings propose, therefore, that surplus is a closely linked symptomatic indicator of impending waste creation, and, as such, the surplus creating effects, or 'surplus footprint' of system processes play a crucial role in food waste creation. Accordingly, food waste prevention targeted at processes of waste creation requires protocols of measurement and disclosure of surplus along the whole supply chain.

6. Conclusions

The research findings illustrate how key actors, such as powerful supermarkets, prevailing supply chain characteristics such as the dominant concentrated distribution model reliant on surplus, and broader systems dynamics, such as competitive focus on growth and output volume within industrial farming, drive overproduction. It shows in context how these mechanisms, and related processes, lead to food surplus that transitions to waste on-farm or in post-production stages. The lock-ins identified suggest that any program to reduce overproduction and concomitant food waste due to its governance arrangements will be met with high levels of resistance. The prevailing business model and deep-seated cultural and cognitive perceptions regarding the nature of product quality and waste not only promote overproduction and surplus formation but create a dependency on these features for the supply chain to function. Consequently, Australian horticultural food chains lack the purpose and infrastructure to recover value from food surplus. Moreover, rather than preventing surplus from going to waste, supply chain practices accelerate food waste creation due to their fundamental reliance on overproduction and surplus-creating processes. The research findings indicate that monitoring surplus may be considered a contributing method of food waste prevention. Beyond surplus monitoring, the findings also suggest that, without altering the fundamental characteristics of current supply chains, systemic overproduction will continue, ensuring large volumes of food are wasted.

This paper contributes to the in-depth understanding of systemic processes and mechanisms underlying overproduction, surplus and food waste creation by identifying and explaining relevant system phenomena within the Australian horticulture supply chain. The theoretical perspective of lock-in allows a demonstration of the broader significance of the research findings for sustainable food systems, specifically a theoretical conception of food waste as symptomatic of food system lock-in and resistance, enabling further theorizing of systemic food waste prevention from a socio-technical system perspective. At the same time, the detailed analysis of 'food waste lock-ins' contributes to socio-technical theory by increasing understanding of specific aspects of regime persistence as well as preconditions for transitions.

The identification of specific phenomena of food chain lock-ins also provides tangible direction for gradual interventions by policy makers, industry managers and food waste researchers alike. In this regard, the findings suggest three key recommendations: Firstly, future efforts to combat, measure and conceptualize food waste should address systemic processes of food waste creation along the whole supply chain rather than focusing on single points or individual actors. Secondly, horticulture food chain governance should target interventions combating systemic food waste at the processes contributing to institutional, cultural, and technical-material lock-ins. The lock-in analysis thus presents not only a diagnosis of the present state, but also a prescriptive agenda for future change. Thirdly, further research, and related governance responses, should focus on exploring and monitoring how surplus flows through food chains, i.e. what we term the 'surplus footprint'. A central conclusion of this research is that such governance arrangements should focus on open and transparent monitoring and disclosure of surplus volumes along whole food chains as a prerequisite for systemic food waste prevention.

CRediT authorship contribution statement

Rudolf Messner: Conceptualization, Investigation, Formal analysis, Writing - original draft. **Hope Johnson:** Writing - review & editing. **Carol Richards:** Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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5. Systemic Food Waste Prevention as a Transition Pathway to Sustainable Food Systems (Paper Three)

Under review

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Preamble:

Paper Three addresses Research Question Three, “What is the (theoretical) significance of systemic food waste prevention for transitions to sustainable food systems?” Having established systemic food waste as “surplus-to-waste lock-in” of food system processes, this paper presents solutions and conceptualises food waste prevention as “escaping lock-in”. The research findings reported in this paper partly overlap with Paper Two as each paper is designed as a stand-alone article, which necessitates presenting the waste and surplus causes together with the solutions that emerged from the research interviews. Solutions to systemic food waste are discussed as escaping food system lock-ins within an overall transition management approach of dominant regime destabilisation and alternative niche support. Accordingly, food waste prevention is conceptualised as a possible pathway of food system transformation to greater sustainability.

Title Page:

Systemic Food Waste Prevention as a Transition Pathway to Sustainable Food Systems

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Abstract

Food waste is a major challenge tied to broader global issues like climate change, resource depletion and food insecurity. Food waste reduction is a key objective via Goal 12 of the United Nations Sustainable Development Goals, which sets a global target of halving food waste by 2030. Despite food waste being part of a large-scale problem and food waste prevention being part of the solution, the complex ways in which food systems produce food waste has not received attention proportionate to the scale and impact of food waste. To best identify ways to reduce food waste, this paper argues that food waste should be conceptualised as a structural characteristic of (unsustainable) food systems. This paper presents findings from qualitative research into the Australian horticulture industry that illuminates how food waste is fundamentally linked to underlying food system processes. Through the lens of socio-technical transitions theory, this paper highlights how food waste results from a system locked into a deeply ingrained cultural, regulatory, material and economic reliance on overproduction and food surplus. Accordingly interventions focusing on "creative regime destabilisation" and "sustainable niches" can open up spaces that enable approaches of shared responsibility for food waste prevention across the supply chain rather than narrow, ad-hoc responses that fail to account for the systemic nature of food waste creation.

Keywords: systemic food waste, food systems, sustainable production and consumption, transition management, surplus/waste lock-in

1 Introduction

Food surplus and waste are acknowledged as having a negative impact on climate change, resource use, food security and dietary health (Capone et al., 2014; Friel et al., 2014; Lemaire and Limbourg, 2019; Porter et al., 2016; Vermeulen et al., 2012). While these challenges have been studied in relation to food systems (El Bilali, 2019; Ericksen, 2008, 2012; Lang and Ingram, 2013), food waste, as a distinct field of scholarship, has only recently attracted attention in food system research (Hodgins and Parizeau, 2020). However, food system conceptualisations that encompass food waste tend to position food waste as a visible, unsustainable food system outcome, as an inconvenient material to be managed or an outcome of consumer behaviour to be corrected (Ingram et al., 2013: Principato, 2018; Raak et al., 2017). These approaches recognise food waste as broadly linked to food system processes and yet are out-of-step with emerging food waste research that increasingly conceptualises waste as endemic to industrialised food chains and broader food systems functions (Corvellec et al., 2018; Mourad, 2016; Redlingshöfer et al., 2020; Thyberg and Tonjes, 2016).

This research deepens the emerging conceptualisation of food waste as an endemic feature of complex food system interactions by providing practical and theoretical insights into how food waste is an ingrained feature of prevailing food systems' practices and processes. By drawing on the findings of an empirical study into food waste and the Australian horticulture supply chain, this paper extends previous research, which identifies the systemic causes of overproduction, surplus and food waste (Messner, Johnson and Richards, 2020). The leads to the identification of possible systemic solutions to food waste in primary production and processing. In particular, this study addresses the multiple factors that can link food waste and its prevention to food overproduction and surplus creation. In doing so, this research strengthens the empirical and conceptual basis of a "system perspective" of food waste and highlights the radical and important role of systemic food waste prevention and related actor responsibilities to intervene.

Findings are analysed through the lens of socio-technical transition theory, which is a systems-based framework commonly employed to conceptualise transitions to sustainability (broadly speaking). This

approach has also proven useful in assessing changes towards more environmentally and socially sustainable food systems (El Bilali, 2019; Hinrichs, 2014) but as yet, has not been applied to the issue of surplus food production and waste. The theory extends here to identify intersections that entrench surplus and waste, that is, 'lock-ins' to surplus and waste creation (Geels et al., 2014; Köhler et al., 2019). In particular, the findings reveal that context-specific, technical-institutional factors have enabled surplus and waste creation while related interactions limit alternative supply chains, typically referred to as niches in transition theory. From this, ways of escaping "surplus-to-waste lock-ins" within Australian horticultural supply chains (Messner, Johnson and Richards, 2020) are conceptualised by focusing on the dynamics that enable and rely on overproduction and the front-end of the supply chain more generally. As such, this paper advances a systemic understanding of food waste as a contributor to unsustainable *aggregate resource use* along whole food chains[4], i.e. the total amount of resource use within an entire supply chain, rather than at any distinct stage or actor. As such this study explores empirically and theoretically how the systemic prevention of food waste can contribute to designing more sustainable food systems.

This paper is structured as follows: The next section presents the context and background to this research and reviews the extant literature on food waste and sustainability. The paper then turns to the theoretical framework of transitions to sustainability, with a focus on transitions of dominant industry regimes characterised by institutional-technical lock-in (Unruh, 2000). Then, the qualitative research methodology is described, before discussing four key aspects of the systemic food waste problem and its conceptual implications for the management of transitions to food system sustainability.

[4] Conceptually, the measure of aggregate resource use aligns with United Nations Environment Program governance frameworks proposing systemic appraisal of resource use (UNEP, 2017).

2 Literature: Food waste, Responsibilities and Sustainability

It is difficult to settle on a singular definition of food waste because of its pervasive role in numerous and diverse global challenges of sustainable development (FAO, 2019, p.2; also see Koester, 2014). Moreover, food waste definitions are underpinned by normative and political motivations and preferences (Corrado et al., 2019; Chaboud and Daviron, 2017) as well as by processes of social construction that determine what society considers 'waste' (Gille, 2012). Regardless, a common and broad understanding of food waste is "the removal of materials intended for human consumption from the food supply chain" (FAO, 2019). For this research, therefore, we considered food waste to refer to *the use of resources that go into producing and processing food that is either not eaten or not needed to be eaten by humans*.

This understanding of food waste especially links with questions around the distribution of harms from food surplus and waste as well as the benefits (and foregone benefits) of food surplus and waste and finally the collective responsibilities of supply chain actors versus individual actors (Kaiser and Algers, 2016). After all, global food production is one of the most, if not the most, resource-intensive activities humans undertake (FAO, 2014; Hoekstra, 2012; Kummu et al., 2012; Lundqvist et al., 2008; Springmann et al., 2019); meanwhile, food systems discard, depending on the measurement protocol deployed, 30-80% of food mass and nutrition value (Alexander et al., 2017; FAO, 2019; Vulcano and Ciccarese, 2017; WRI, 2019). The global over- and under-consumption of food has long signalled significant distributional inequalities. Moreover, research has questioned "the legitimacy of the virtually unlimited entitlement producers and consumers have to produce waste" (Corvellec et al., 2018, p.18). Consequently, preventing food waste emerges as an important prerequisite to transition to more sustainable and equitable food systems.

Food waste prevention is typically positioned as the main priority for food waste interventions. Researchers have argued, however, that prevailing efforts to *prevent* food waste mainly "deal with food

waste once it exists rather than preventing it from occurring in the first place", or shift blame to consumers by excessively focusing on their wasteful behaviour (Messner, Richards, Johnson, 2020, p.805). The conceptual ambiguity of the nature and purpose of food waste prevention has thus led to the "prevention paradox"; that is, an over-emphasis in food waste responses on end-of pipe and ad-hoc solutions selectively focusing on individual supply chain actor behaviour and responsibilities rather than systemic prevention, which targets the processes of intentional and unintentional food waste creation.

In regards to systemic prevention, researchers have identified overproduction as a key fundamental characteristic of food systems that are interlocked with food chain processes and food surplus creation (Chaboud and Daviron, 2017; Papargyropoulou et al., 2014; Mourad, 2016; Pedersen et al., 2015; Vulcano and Ciccarese, 2017). Empirical evidence shows that food production has moved from fulfilling to surpassing global nutrition requirements resulting in overconsumption and increasing food waste (Cloke, 2016, p.101; Hall et al., 2009, p.2; Hic et al., 2016, p.4275). While increasing production has a long history of being framed as the panacea to food insecurity, the overproduction of food has not resolved food insecurity (Sen 1981). Indeed, food systems are now more vulnerable to shocks in part due to the contribution of intensive agriculture to global environmental challenges (Carolan, 2018; Vermeulen et al., 2012).

Recent research has revealed how food waste is fundamentally linked to food system processes and characteristics that depend on overproduction and food surplus, offering a conceptualisation of food waste as a symptom of food system lock-in into unsustainable practices of production and consumption (Messner, Johnson and Richards 2020). Accordingly, the concept of 'surplus-to-waste lock-in' uncovers the systemic formation of surplus and waste and the amplifying impacts of food surplus on waste creation. The research concluded that food waste prevention requires systemic rather than ad-hoc approaches, including the transparent monitoring and disclosure of surplus in supply chains.

The systemic view asserts that selective measures to reduce food waste may benefit certain actors and parts of the supply chain to the detriment of others in ways that are unequal or create unintended

consequences (Chaboud and Daviron, 2017). It, therefore, calls for a holistic approach to food waste prevention across the whole food supply chain (Halloran et al., 2014; Hodgins and Parizeau, 2020; Mourad, 2016) including proposals to measure “aggregate food waste and resource use for separate products along the supply chain” (Koester, 2014, p.352). As such, systemic prevention of the creation of food waste does not seek narrow responses to the material waste alone (Corvellec et al., 2018) nor does it permit an externalisation of the food waste problem to other parts of the supply chain or society (Chaboud and Daviron, 2017; Clapp, 2014; Parker and Johnson, 2019). This systemic perspective of food waste connects with sustainability and responsibility “in relation to food all along the value chains” (Kaiser and Algers 2016, p.1).

To enhance understandings of systemic food waste, research has called for further “evidence” and “deeper analysis” of the detailed linkages between food system characteristics, processes and food waste as an outcome (Halloran et al, 2014, p.295; Vulcano and Ciccarese, 2017, p.46). Others have posed questions regarding the factors that make food systems prone to producing large amounts of waste and have encouraged researchers to focus on the underlying determinants of food waste creation (Bengtsson et al., 2018, p.1542; Redlingshöfer et al., 2020, p.9). These determinants include “decision processes and actors within the lock-in of unsustainable activity” (O”Rourke and Lollo, 2015, p.242), relationships and automatisms in the food chain (Göbel et al., 2015, p.1441) and food waste as an “intrinsic element of food systems” (Hodgins and Parizeau, 2020, p.43).

Responding to these knowledge gaps and further extending previous research on “surplus-to-waste lock-in”, this paper specifically aims to present empirical evidence from the Australian horticulture industry capturing systemic causes of food waste creation and possible systemic remedies. To conceptualise the empirical findings on the systemic causes of food waste and to identify solutions, this research adopts the theoretical perspective of “transitions to sustainability” to be outlined in the next section.

3 Theory: Creative De-stabilisation and Transition Management

This section describes how socio-technical theories help identify pathways for sustainable transitions. Socio-technical systems are a conceptual frame that comprehensively captures the complex interactions that enable systems of production and consumption. Such a framework is uniquely suited to ethical, normative analyses of food issues, as food ethics promotes a "systemic understanding of problems and perspective of sustainability" (Bui et al., 2019, p.277).

Major environmental and social challenges derive from "patterns of unsustainable production and consumption" deeply embedded within socio-technical systems (Köhler et al., 2019, p.2). Addressing these major challenges requires profound transformational shifts of technology, politics, business, and culture in dominant socio-technical systems, which process is termed "sustainability transitions" (Geels, 2011, p.25). Transition management refers to the multiple ways in which actors intervene in an unsustainable socio-technical system to achieve transformational change towards long term goals of more sustainable systems (Köhler et al., 2019; Loorbach and Rotmans, 2010). These transformations are understood, from a multi-level perspective (MLP), as occurring from interactions within and between the socio-technical systems, comprised of regimes and niches, and externally to the system, i.e. landscape-level changes (Geels, 2010).

Regimes is a term to describe dominant and stable socio-technical configurations. In the context of this study, regime refers to the primary food chain for horticultural products in Australia and its related aspects such as the rules, knowledges and infrastructure. Actors in Australia's horticultural supply chain have unequal power to influence processes, which reflects well-studied dynamics in other regimes whereby particular actors accrue disproportionate power over the regime giving them the ability to shape and stabilise the socio-technical system over time (Geels et al., 2014; Turnheim and Geels, 2012).

Regime stability and dominance are, by definition, characterised by “lock-in” (Geels, 2011, p.27). Lock-in refers to suboptimal path dependency, that is, an “established convergence of seeing and doing things” (Svingstedt and Corvellec, 2018) that perpetuates unsustainable and inefficient practices causing market and policy failures (Unruh, 2000, p.817). Research has described a particularly powerful lock-in that occurs when private enterprise and governing institutions override market forces to form a technical-institutional complex (Geels et al., 2014; Unruh, 2000; Seto et al., 2016). A lock-in to particular technical-institutional configurations contours how, and if, transitions occur even where the existing configuration is “causing disutilities, unintended consequences and negative externalities” (Unruh, 2002, p.318).

Innovative and radical niche solutions may challenge locked-in regimes and its dominant actors. Niches are spaces within a socio-technical regime that incubate innovation and may act as catalysts for socio-technical transitions. Often, transitions are mergers and conflicts between niches and regimes. However, a conceptualisation of transitions as regime-niche conflicts is inappropriate in cases of overwhelming industry regime dominance (Smith et al., 2005) or where a system lacks established niches (i.e. alternatives) (Sengers et al., 2016). In such cases, the focus should not be so much on niches (or the landscape level) as the primary catalyst for change; rather the focus for transitions studies should be on the regime actors and configurations and how they have changed and stabilised over time (Geels et al., 2014). Accordingly, “regime destabilization” has become a program of study within socio-technical transitions research (Turnheim and Geels, 2012, 2013).

Regime destabilisation conceptualises how, while some regime dynamics reinforce, other dynamics within a regime can be a source of challenge and change. It refers to those dynamics within a regime that emerges to increasingly cast doubt on the suitability of the regime itself i.e. interactions that scrutinise existing practices, business models and beliefs. These dynamics progressively weaken the legitimacy and reputation of, and commitment to, existing regime configurations (Geels and Schot, 2007; Turnheim and Geels, 2012, 2013).

The interactions that makeup niches and regime destabilisation are different. Niches, after all, focus on the creation of alternate regimes, while regime destabilisation processes gradually weaken and destruct from within existing regimes. Yet, both processes enable socio-technical transitions. Researchers have described niches and regime destabilisation processes, therefore, as bi-directional transition processes (Turnheim and Geels, 2012, p.48). For instance, Alkemade et al. (2011, p.127) argued that the purpose and objective of transition management cannot merely be the creation and dissemination of alternate technical and social innovation, but also the necessary "phasing out" of incumbent regimes. Kivimaa and Kern (2016, p.205) invoke the concept of Schumpeterian "creative destruction" to highlight the linked processes of creating alternative niches in the spaces opened by "the withdrawal of support from the old regime".[5]

Once problems with the dominant regime practice become widely apparent, progressive destabilisation will force corporate and institutional actors in a socio-technical system, including at the landscape level, to choose between three basic transition approaches (Unruh, 2002, p.318). The commonly preferred option chosen by incumbent regime actors is managing the "end of pipe" product such as carbon emissions or food waste, without changing the underlying system that caused it in the first place. The second approach seeks to protect continuity and will concede a minimum of changes within the boundaries of the dominant regime. The third approach is more challenging in the short-term as it calls for the discontinuation of an incumbent regime and its replacement with a new system configuration.

Transition management perceives its primary objective as "creating a social movement around visions and goals, and, as a form of meta-governance, safeguarding the long-term transition orientation by influencing subsequent transition governance activities" (Loorbach and Rotmans, 2010, p.239). Hence,

[5] An example of withdrawing unsustainable regime support is the US$650 billion in global annual subsidies to the fossil fuel industry, provided by governments to incumbent unsustainable dominant industry systems (Turnheim and Geels, 2012, p.48). Dominant regimes also receive government support in terms of policy, legislation, regulation, tax, public resources, research, training, education, investment and other items that stabilise existing regimes and create entry barriers for sustainable alternative solutions (Galli and Brunori, 2013).

transition management should seek to resolve competing trajectories for changing the incumbent regime and develop a common *purpose and vision for sustainable transformation* through stakeholder collaboration and contestation (Geels, 2010; Savaget et al., 2019; Smith et al., 2005; Vittersø, and Tangeland, 2015). Eventually, a common vision for how to transition a system emerges over-time from these interactions based around actor resistance, active support or passive acceptance (Grin, 2011).

The theories underlying transition management of niches, regime stabilisation and resistance can be misconstrued as referring to a group of unified, industry actors, processes and infrastructure with a common purpose or understanding. Yet, underlying socio-technical transitions theory is an acceptance of complexities and ambiguities. Far from representing "homogenous bigness" (Gille, 2016, p.95), dominant industry regime configurations include phenomena such as "hybrid actors", e.g. regime actors sympathetic of niche proposals (Darnhofer, 2015, p.23), selective adoption of innovations and solutions in order to perpetuate regime stability (Kivimaa and Kern, 2015; Smith, 2006), and "countervailing industry interests", which raise the possibility of coalition-building in order to leverage transformational change (Hess, 2014; Meadowcroft, 2011). Effective change requires the formation of "networks of actors possessing the wherewithal to adapt the incumbent regime or create alternatives" (Berkhout et al., 2003; also see Scoones et al., 2020). At the same time research has highlighted the distinct role of governments at the landscape level (Johnstone and Newell, 2017) as the state commands unique powers to develop and enforce legislation or policies for niche or regime destabilisation to break unsustainable lock-in and regime resistance to sustainable change.

4 Methodology

This research was designed to explore evidence of food waste causes and approaches to food waste prevention considered appropriate to actors within the Australian horticultural food chain. Moreover, the research sought to provide a theoretical account of the role of food waste prevention within transitions of prevailing food systems towards more sustainable modes of production and consumption. Accordingly, the research was guided by central questions addressing an empirical and a theoretical component: *What are the*

causes and solutions to food waste in the Australian horticulture supply chain? What is the relevance of food waste prevention for transitions to food system sustainability?

Institutional and individual actors within the supply chain have the primary knowledge and experience about food waste causes and possible solutions in the supply chain before the consumer-level. Therefore, this research applied a qualitative interpretive methodology based on a series of semi-structured interviews with key industry actors in the Australian horticultural supply chain (Cresswell and Poth, 2018).

The data sample consisted of twenty-eight interviews of approximately forty minutes with growers, processors, senior industry peak body representatives as well as industry experts. A focus of the sampling strategy was to ensure 1) maximum range of perspectives across the diverse horticulture industry sectors and 2) participation by growers supplying to Australian supermarkets and wholesalers, the two channels delivering the largest volumes of fresh food to the market (IBIS World, 2019). In addition to capturing the mainstream conventional industry segments, this research also specifically included several participants at points along the supply chain that are closely related to production such as initial processing and on-farm or near-farm waste management.

The interview protocol included general questions about management practices in regards to surplus production, food waste causes and possible solutions or appropriate approaches to food waste prevention. Interview questions included: What are prevailing management practices in regards to waste prevention in your industry? What causes food waste on farm and what do you see as potential solutions? How do you relate to food waste prevention and sustainable agriculture?

Data analysis was informed by “adaptive theory” (Layder, 1998, 2018), a methodology of data analysis, which seeks to explain, rather than describe, social phenomena by connecting human activity to social structures (Van Gramberg, 2006). Data analysis consisted of ‘provisional coding’, a process that combined concepts emerging from the data with theoretical orienting concepts. This approach has been described as “analysis with theory in mind” (Layder, 1998, p.2). Accordingly, data analysis followed iterative adaptive cycles of

thematic coding and concept development, thus enabling interpretation and explanation of life world phenomena and underlying system phenomena relating to food waste creation as well as its prevention (Carter and Sealey, 2000; Hewege and Perera, 2013; Layder, 2018). Social Domain Theory offers specific capabilities to build theory from empirical cases by connecting the micro and macro levels of analysis and incorporating individual agency within the social context through the emergent social domains of 'psychobiography' and 'situated interaction'. This analytical approach helped to connect individual practices of growers, e.g. discarding surplus food on-farm, and important interactions, e.g. meetings with supermarket buyers, to broader system settings and context. In this regard, this research contributes by applying Social Domain Theory as an explanatory framework that is epistemologically congruent to transition research, which the sustainability transition research agenda has highlighted as a desirable direction for further theory development (Köhler et al., 2019, p.6).

The research findings reported below purposefully privilege the voices, knowledge and experiences of actors in the Australian horticulture food chain to offer an account of the causes of surplus production and food waste from those closest to the phenomenon.

5 Research Findings

Respondents reported a wide array of wastes occurring on farm due to specific causes and events some interviewees called "the vagaries of farming". These include weather events such as storm and hail, pest and disease, poor farming practices and agronomic management, harvest damage and handling damage in the supply chain. Beyond such very specific causes of waste, respondents also described waste caused by the arrangements, design and interactions in the horticultural supply chain, including processes, conventions and mutual understanding of how the business works. While the quantification of farm waste was not a primary objective of this research, some respondents, provided estimates within the interviews, which indicated an average range of on-farm waste, including field waste and packing shed waste, between 20% - 50% of total annual production. These estimates serve only as an indication

of how respondents assess the significance of farm waste from their experience. The following section is organised around the dominant themes evident in the interview data and is organised to capture the "voice" of the participants.

5.1 Competition Reduced to Price

Research respondents described the prevalence of large amounts of surplus produce ploughed in or disposed of on farm, without entering the fruit and vegetable supply chain. While surplus and shortage are often seen as specific to crops, seasonality and product life cycle, most research participants gave evidence of substantial surpluses resulting from overproduction as a prevailing industry practice. The interviews identified several market characteristics and practices to explain the phenomenon of overproduction, specifically practices of competition, the growth and productivity paradigm within the industry and the difficulty to transition to alternative modes of production.

Interviewees have presented a view of the Australian fresh food supply chain as defined by a high degree of concentration of distribution channels and limited alternative routes to access mass markets. The increasing concentration forces growers and suppliers to compete for limited supermarket contracts by accepting their standards and specifications, trade terms and competitive pricing. Respondents explained how a key consideration is always to ensure sufficient product availability to supply supermarkets. A failure to supply at the right time and right price will result in lost business as competitors will readily step in. As a Queensland vegetable grower explained, overproduction has become a necessary part of the business and something "everybody does".

There was strong agreement between interviewees that competition relies almost exclusively on low price, which requires cost-efficiencies normally achieved by specialisation, intensification and scaling-up of production. Indeed, interviews described common measures to reduce cost as increasing land under cultivation, specialising on a narrower range of crops, investing into equipment and automation, buying high yield solutions with the agronomical advice from agri-chemical companies or downgrading resource

inputs. Indeed, research has described how this co-evolution of a highly concentrated supermarket sector and intensive industrial agriculture as the standard model for fresh food chains has profoundly re-shaped the business practices within dependent supply industries, such as horticulture (Burch et al., 2012a; Pretty et al., 2012; Rayner et al., 2008; Richards et al., 2013). Hence, the process of "supermarketization" (UNEP, 2017, p.62) is a source for fundamental structural power asymmetries in the food supply chain (Devin and Richards, 2018; Ghosh and Eriksson, 2019).

While industrially intensified approaches achieve lower cost on a narrow range of items, growers were aware they come at a price of increased exposure to the "problems of monoculture" such as weather damage, disease and pest. The interviews reflected on how the continuous need for investment increases the dependence of growers on intensive industrial methods and how while reinforcing transition barriers to alternative business models in terms of cost, competition and risk to livelihood. Some growers pursued business models focusing on margin rather than volume, producing to order rather than maximising yield, and "only growing what they can sell at a good price". Such an approach to business, however, was the exception rather than the norm. Growers fully invested in the intensive industrial growing model generally considered it beyond their means to undertake profound change.

Importantly, interviewees highlighted how intensive practices also increase the economic vulnerability of farms to price fluctuations, which are a major cause of on farm waste. Indeed, once all investments have been made, growers compete on a narrow range of crops, for narrow windows of time at narrow profit margins, a risky game that can result in either large volume sales or surplus. Real market demand is largely invisible to growers, who take cues from buyers or competitors encouraging them to produce more, or they simply always produce the maximum they can to service their debt. As one grower summed up, "The industry is set up to force us to overproduce, there is no margin to produce less".

In a concentrated market with limited alternative mass-market channels, the sustained oversupply of produce thus emerged as an important facilitator of low market prices, which may deplete gradually, leaving producers more vulnerable to sudden downturns. In contrast, oversupply enables supermarkets

to deploy strong measures to further reduce price such as “open book negotiations” [*full producer cost transparency*] or “reverse auctions” [*lowest bidder gets the deal*]. Some respondent recounted the enforcement of previously unenforced cosmetic standards as another common strategy to downgrade price. During peak harvest season and gluts prices decline even more rapidly driven by a significant influx of oversupply. Once the market price falls below the cost of production, growers commonly abandon crop before harvest. Produce represents an embodied value of financial and resource inputs, including harvest labour, packaging, storage and transportation, which the market price has to return. Once that cost cannot be recovered, it is the “financially responsible thing to do, not to harvest but to have food waste instead”.

5.2 Quality Reduced to Appearance

Nearly all interviewees agreed that the strict quality standards and specifications for horticultural produce defined and enforced by supermarkets were a predominant cause of food waste creation in horticulture. The interviews reflected how supermarket specifications are primarily measures of superficial appearance, aiming at strict uniformity of size, colour and shape, rather than “eating quality” such as nutritional value, variety and taste. As such cosmetic standards support Australian supermarkets” objective to sell what they determine to be premium product exclusively. Research participants explained that sales of “acceptable” premium grade product offer better financial returns on single consignments than discounted second grade. However, as an industry representative from Melbourne explained, these financial returns do not “count the waste of rejected produce or “seconds”, which supermarkets “rather push back into the supply chain than sell”.

Again, oversupply, the availability of produce more than market demand, emerges as the key enabler to achieve maximum cosmetic uniformity. Interviewees described how, during periods of short supply, supermarkets concede variances on their standards to fill the shelves. An oversupplied market, flooded with premium level product, offers abundant rather than limited choice, thus ensuring maximum

compliance with the strictest premium class standards. However, wider choice of surplus implies larger amounts of non-compliant or out of specification product, which in the absence of real alternative mass distribution channels, mostly ends up as waste. As a technical manager of a Queensland fruit growing business described cosmetic grading during peak season oversupply, “Stuff that would normally get packed in second class will just get dumped”.

Research has widely described this form of waste creation beyond the boundary of supermarket store operations, *caused* by the enforcement of supermarket cosmetic standards, including waste from rejected, pre-emptively discarded, or ploughed-in produce, (Beausang et al., 2017; de Hooge et al., 2018; Johnson et al., 2018; Porter et al., 2018). In this regard, the interviews have added to the extensive evidence of supermarkets applying their significant structural power within the food chain to externalise waste to other parts of the supply chain or cause food waste not to leave the farm at all (Devin and Richards, 2018; Feedback, 2018; Ghosh and Eriksson, 2019). Hence, other nodes along the supply chain, as well as future generations, are disproportionately burdened with food waste.

The business model of selling only cosmetically perfect fruit has become established over time and was perceived by respondents as a consequence of mass marketing practices and investments into the conditioning of consumer and grower perceptions of cosmetically preferred produce. Firstly, because of the disconnect between growers and consumers, respondents doubted the extent to which supermarket standards reflected “real” expectations or just represented “supermarket attitudes”. Even if individual consumer preferences matched supermarket standards, their preference is shaped by a wider “shopper socialization” by supermarkets (Burch et al., 2012a). Secondly, respondents observed how cosmetic standards had shaped the number and kinds of growers, that is, only growers that had the capacity to accept the additional cost and wastes remained in the industry. The practice of applying cosmetic supermarket specifications is supported by a tacit agreement between industry and government. The position and know-how to set and enforce food standards is, in effect, devolved to self-regulating supermarkets. Yet, supermarkets have few incentives to reduce on-farm waste leading to a broader lack of interest and incentive to consider food waste prevention a policy priority even among grower

associations. Rather, the interviews confirmed that many growers have come to accept cosmetic standards and the associated waste on their farms as natural.

Research respondents proposed that a change in the approach to supermarket standards could translate into immediate and very significant reductions of food waste creation in the food chain. Growers are generally not opposed to standards governing quality and integrity of food products. Yet, many call for changes and flexibility in the definition and implementation of standards to achieve "broader and more open acceptability" of nutritionally adequate produce to prevent it from being discarded for reasons of cosmetic appearance alone. A grower pointed to a box of grading waste, "I would eat that, why is it not going to market". An industry peak body representative questioned the legitimacy of cosmetic standards: "Consumers are willing to accept imperfect produce but supermarkets simply don't want to sell it".

Recently supermarkets have started promoting "imperfect" fruit, but on a small scale and clearly separated from premium produce. Respondents saw this approach as a superficial response by supermarkets to increased scrutiny of its standards rather than a genuine effort to reduce waste. They also expressed concerns about how "ugly" fruit sales could further distort and devalue the market and further disempower growers. As one respondent said, "They're still perfectly safe to eat, they are still just as fresh and they have cost the farmer and the environment the exact same amount of resources to grow". Respondents proposed interventions based around "re-education" along the *whole food chain* and at household level to reverse current cosmetic expectations and perceptions for produce enforced by supermarket standards.

5.3 The Lack of Supply Chain Diversity

Growers perceive that excessive power and the lack of food retail diversity and transparency have not only shaped practices of competition and pricing that lead to waste creation but also other inefficiencies contributing to waste further along the supply chain. Respondents have described the prevailing

dominant food distribution model as overly centralised, resulting in inflexibility, wastefulness, and an inability to deliver food, which is fresh, locally grown and of sufficient nutritional variety.

A Melbourne distributor pointed out that the key capability of a functioning fresh food chain, as opposed to dry goods or toiletries, is to deliver food fresh. A Victorian grower added, “The cheapest and freshest produce is locally grown and in season”. Yet respondents did not generally consider their produce to be fresh by the time it reached supermarket shelf, as it generally takes 10-14 days to reach the market, which diminishes eating quality and its remaining useful life. Respondents considered diversity to be essential for fresh food supply chains to contribute to dietary diversity, to increase resilience and profitability of farms and prevent food going to waste.

Yet, the current model, based on market concentration and specialisation, has actually resulted in a significant reduction of produce variety, and a declining number of farms, which reinforces the role of supermarkets and reduces space for alternatives. Indeed, Australia has one of the most concentrated grocery markets in the world with major supermarket chains controlling over 80% of the fresh food market and the top two supermarkets over 50% of the fruit and vegetable market, with concentration steadily growing in their favour (Fels and Lees, 2018; Salardini, 2019). As a key improvement to many shortcomings of the food chain, interviewees suggested, was increasing the diversity of distribution channels. They described deliveries from farms to local markets, independent stores or even to households, as decentralised alternatives or supplements to the dominant long-distance and centralised supermarket cold chains. While growers see a real opportunity for diversity and variety, in terms of products and distribution channels, the interviews have emphasised the crucial importance for any alternative model to achieve “appropriate scale” in order to become a realistic option for full provisioning of households rather than just weekend shopping.

Another key facilitator of supply chain innovation to reduce oversupply and waste creation was seen as demand transparency, which is perceived as very limited within current supply chains. Some respondents proposed technologies such as block-chain, which could be deployed to increase supply

chain transparency and traceability supporting competition within more open and visible market settings. Technology can also provide a platform for a renewed connection of fresh food producers with consumers, previously lost in the prevailing centralised cold chain model, and enable supply chain innovation following new trends including the cultural emphasis on healthy, place-based, traceable and/or local food and the related rise of farmers markets.

Despite the availability of technology to improve the supply chain in various ways, others were less hopeful that the current food chain could transition from its prevailing high waste retail model. The major challenge, as a Melbourne based peak body representative pointed out, is not technology but to get everybody into one room and agree on such significant transformations.

5.4 The Uncertain Value of Surplus

As surplus and oversupply remain a prevailing feature of the fruit and vegetable industry, respondents described approaches to managing and preventing it from going to waste. Due its perishability as well as the large volumes, a very narrow opportunity exists to use surplus once it has accumulated at the farm level. Only marginal channels and opportunities outside of mass retail exist for the re-use of surplus produce and dumping produce as interviewees described waste as the most common outcome. One respondent explained, “Anything that hasn’t gone into a supermarket level container can be technically classified as waste”, and, “Selling elsewhere is not worth it”, are different ways respondents assess the basic choices at their disposal.

As research participants were aware that domestic production has been exceeding demand in many industry segments, they questioned the meaningfulness of calls for further industry growth targeted by government and industry leaders. Indeed, Australian agricultural industries have outlined plans to grow production output substantially (e.g. NFF, 2018). Respondents, however, gave evidence of substantial surplus in key industry sectors, describing 40% of industry output as “already sitting there on farm” but

not being utilised due to supermarket standards. Considering the significant resource use of agriculture in arid Australia, including the withdrawal of 65% of total freshwater supply (Friel et al., 2014; Pagotto and Halog, 2016), the most obvious management response is to produce less to reduce the un-needed resource use. However, despite specifically acknowledging the significant waste of resources, respondents generally expressed that reducing production levels through any form of restriction is not feasible in Australia, especially in the absence of related subsidies used in other markets. “Commercial reality will not allow that, people will still need sales”. Besides, also competition will prevent farmers from reducing production as competitors will simply respond by producing more.

One perspective considers surplus as a problem of “under-consumption” as fresh fruit and vegetables consumption per capita has barely gone up over the last two decades. Some have therefore proposed stimulating demand for fruit and vegetables in domestic and export markets to reduce surplus while encouraging healthier diets. Others are less optimistic and view demand stimulation as a purely short-term measure, as supply invariably catches up to restore oversupply, it is “like chasing your own tail”, as one industry peak body representative put it.

If the surplus itself is not preventable, the waste resulting from surplus might be. To re-purpose surplus, respondents proposed value-added product innovation. Although enthusiastic about this pathway, respondents named substantial operational, logistical and economic obstacles that prevent large scale re-use of surplus. In trying to recover value from surplus produce, growers must first invest further into transportation, handling and shipping to a new destination. Selling to processors was seen as a solution, yet processing itself is a declining industry in Australia due to lack of international competitiveness. Moreover, research respondents have described how surplus product still must be suitable for processing and competitive versus produce from other sources in terms of cost, reliable supply, and ability to be transported long distances). In sum, the interviews show that making products as opposed to growing produce requires an entirely different skillset and substantial investments not only into know-how, equipment, R&D and intellectual property protection but also into market access and demand creation.

Considering these significant challenges, one industry sustainability manager explained that value-added product innovations are not a panacea to *large scale surplus and waste*, but rather represent new supply chains with their own waste creation. Indeed, some respondents argued that businesses built on product innovation need to be investments in their own right with a purpose beyond mere surplus disposal. Certain varieties of crop offer high versatility and suitability for product processing, such as avocados or nuts, and thus present more management options to prevent large amounts of waste. Accordingly, value-adding and innovation can be strategies to achieve increased versatility and diversity of various horticultural products, while simultaneously supporting demand creation for healthier diets. The purpose of this kind of value-adding and innovation is to produce differently and for different purposes, rather than for the sole purpose of removing surplus and waste to create space for more surplus production.

5.5 *Incentives to Change*

The solutions proposed and discussed by research participants imply substantial transformations of the existing supply chain, consumer culture and business practices. Research respondents strongly believe that such transformation, in fact any significant change, is only possible if economic structures incentivise it. As the current dominant supply chain limits alternatives and does not provide incentives, waste prevention is not a priority for the industry. A sustainability manager stated, “there aren’t even any solutions being discussed” as industry leadership does not place an important focus on the waste issue.

Respondents largely discounted consumer choice as a catalyst for change, as they viewed consumers as beholden to supermarket practices and disconnected from agriculture. Supermarkets themselves, however, are seen as well-positioned to address the systemic causes of waste, “The supermarkets dictate these things and make growers change”, and “there’s a lot of fear amongst suppliers with the

'chains' and "a lot of growers just do what they say". However, as far as genuinely pursuing food waste prevention is concerned, supermarkets are some of the main benefactors of the current system.

Others believe the issue requires state responsibility and action, as government decisions have a ripple effect, especially for small growers. "We just got to change it. It"s a whole cultural change thing. It"s almost like, you need the big government effort on driving cultural change like we did with seatbelts and safe sex and stop smoking and all of those". Summarising the challenge of transforming the supply chain model, one Victorian industry peak body representative mused, "Why do we continue with a system that makes waste happen? Well it's because you can't get everybody all in a room together to agree to change the system".

6 Discussion and Implications

This section discusses the systemic underpinnings of food waste causes and solutions identified through in-depth interviews with Australian horticulture industry actors and analysed through the lens of socio-technical transitions theory. As noted earlier, the study's guiding research questions are: *What are the causes and solutions to food waste in the Australian horticulture supply chain? What is the relevance of food waste prevention for transitions to food system sustainability?* Specifically, this section outlines how interventions to overcome lock-ins can prevent the production of surplus food *and* contribute to a sustainable transitions agenda for food waste.

1) The Value Creation Paradox

The research participants have provided evidence that the two main causes of waste creation in Australian horticulture production are related to cosmetic specifications and market price setting, which render large amounts of fresh produce unsaleable. Yet retail marketing management considers "value"

or a “good deal” as a margin between *highest* quality (e.g. benefits other standards) and the *cheapest* price (Barnes et al., 2009). In other words, supermarkets are incentivised by profit to procure the highest quality fruit and vegetables at the lowest price, and a concentrated retail sector and abundant procurement options enable this outcome. Oversupply gives supermarket buyers wider choice to pick only the best looking premium products, while simultaneously causing prices to decline in the short term or deplete in the long term. Hence, the research findings indicate that a predominant causes of food waste in primary production is systemic surplus production in a highly concentrated market. Empirically and conceptually, therefore, the research findings draw a straight line from *value-creation* at the retail stage *to waste-creation* at the production stage. The dominant model for food production and distribution is fundamentally dependent on resource waste in primary production, are self-reinforcing and aimed to increase returns to scale continuously.

In turn, significant government intervention becomes unlikely. As a critical component within a highly dominant industry configuration, the Australian supermarket sector is protected from regulator disruption such as increased enforcement of competition laws; institutional and cultural lock-in mechanisms include, and enable, regulatory capture, that is, regulators advancing the interests of supermarkets (Burch et al., 2012b; Carey et al., 2017; Fels and Lees, 2018; Parker, 2014; Richards et al., 2012).

From a transition management perspective, a crucial issue is how to overcome regime resistance and effect change of the prevailing waste dependent paradigm of value-creation in the Australian horticulture food chain. Transition management theory suggests that a transformation of such a fundamental industry paradigm requires a transition purpose or vision to guide adaptations to structural regime frame conditions, as well as advancements of alternative niche solutions (Grin, 2011; Loorbach and Rotmans, 2010; Smith and Kern, 2011). Furthermore, the role of agency and power is paramount. The research respondents have emphasised that currently no dominant food chain actor, e.g. supermarkets, horticulture industry, government, is willing or able to prioritise food waste prevention to an extent that would significantly alter waste creation in supply chains.

The transition challenge thus lies in enabling a “coalition of shared interest” comprising actors from within the dominant industry regime configuration, as well as from outside, such as sympathetic regime actors, representatives of dependent industries, government officers, members of civil society organizations and citizens (Darnhofer, 2015; Geels, 2011; Hess, 2014; Svingstedt and Corvellec, 2018). This governance approach will seek to consolidate existing pockets of support for the larger purpose of addressing needless and deleterious resource waste in the Australian food chain, advocating for a paradigm of competition and value-creation decoupled from dependency on surplus and waste. Over the last two decades, such coalitions have formed, in varying configurations, to pressure regulators to reform Australia’s competition laws in order to address the market power of supermarkets (Australian Commonwealth, 2015; Fels and Lees, 2018). Despite significant lobbying by supermarket representatives and protracted debate, these coalitions have at times been successful. In 2017, for instance, the Federal Government passed amendments to address the misuse of market power by, inter alia, supermarkets. Although these amendments succeeded in creating more legislative avenues to address unequal bargaining positions, existing structural inequalities remain; these include the difficulty and costs involved for individual growers in making complaints to the regulator and the individual growers desire to not fall out of favour their main buyer.

2) Cosmetic Standards and Waste from Unfair Trading Practices

Technical-institutional lock-in dynamics have been apparent in Australia in the significant impact of supermarket standards on supply chain processes and consumption cultures coupled with the lack of external oversight on the design and implementation of such standards (Carey et al., 2017; Devin and Richards, 2018). Highly pervasive cultural lock-ins, or “shopper socialization” (Burch et al, 2012a), have further exacerbated the lock-in mechanisms pertaining to cosmetic standards; consumer perceptions of quality and safety become aligned with, or are assumed to be aligned with, cosmetic standards.

Cosmetic standards lie at the heart of the prevailing value-creation process of supermarkets and, as an instrument of regime stability, self-protection and increasing returns to scale, represent a significant source of market power. Moreover, cosmetic standards have been recognised as part of a wider syndrome of "unfair trading practices (UTP) implicated in food waste generation" in highly concentrated retail markets (EU Refresh, 2019; Piras et al., 2018). Porter et al. (2018, p.876) suggested the use of command-and-control legislation "effectively banning the use of cosmetic characteristics to determine food quality". This kind of intervention, while it could be effective, has to overcome obstacles posed by the design of food chains, such as structural power, the lack of transparency, consumer acceptance, and fear and reluctance of suppliers to raise complaints (Clapp, 2019; EU Refresh, 2019; Fels and Lees, 2017).

While the EU, in this regard, considers regulation as crucial to the policy mix, the regulatory trajectory in Australia has favoured self-regulation via private standards. Australia, more than most other countries, has an especially strong political preference not to be seen as regulating food and agriculture (Larder et al., 2018; Mayes and Kaldor, 2014). After all, Australia was one of the early countries to significantly liberalise food markets and continues to push for further de-regulation of food and agriculture in international trade negotiations (Lockie and Higgins, 2007). Voluntary regulation is thus legitimised as a way to bring about change in the regime without confronting regime resistance.

Supermarkets in Australia are officially implementing "zero waste" practices, and seemingly represent a successful business case of in-store food waste prevention (Arcadis, 2019). Arguably, therefore, voluntary targets are unlikely to achieve any significant further reductions of food waste in the whole fresh food chain unless supermarkets commit to targets that extend beyond the food waste generated within their operation to take responsibility for food waste at other points in the food chain *due to their operation*.

The key challenge for transition management is to produce an agenda detailing increased oversight of unsustainable cosmetic standards and/or their phasing out, while simultaneously scaling-up niche

solutions and alternative supply chain practices. Transition management would need to focus on adjusting the way, and avenues for, competing in the market and re-value attributes relevant to sustainable resource use and ethical food distribution. Interventions should also address supply chain diversity in terms of variety of produce and quality grades as well as shorter and more flexible distribution channels suited to deliver fresh, local and seasonal produce. Accordingly, transition management must focus on reallocating support from dominant industry regimes to entrepreneurial and social innovative niche approaches with the specific *commitment to growing them* to competitive scale. Furthermore, the transition agenda must include broader food system transparency and education to facilitate the necessary cultural transformations that underpin food system transitions.

3) "Cheap food" and Supply Chain Diversity

The interviews highlighted market concentration and lack of alternative business models as obstacles to food supply chain improvements and innovation. Beyond measures of market share, research on highly concentrated industries has presented evidence of even higher levels of "effective concentration" due to systemic and compounding anti-competitive effects at the intersections of pricing power, discouragement of innovation, increase of entry barriers and high leverage in political lobbying (Clapp , 2019, p.617).

In respect of diversity as proposed by many respondents, research has considered alternative models of fresh food distribution, such as local food networks, box schemes, and shorter and diverse supply chains, not only as lower in resource use but also *multi-beneficial* to community and society (Dixon and Richards, 2016; Galli and Brunori, 2013; Kibler et al., 2018; McCarthy, 2014). Shorter and decentralized supply chains are not inherently more sustainable as the distance food travels is not an absolute indicator of sustainability, but they have been considered less resource-intensive and wasteful than centralised long cold chains, especially in terms of waste due to quality standardisation, duration of cold storage between harvest and consumption, use of non-renewable energy, and the use of plastic packaging materials (Galli and Brunori, 2013).

Technologies to increase transparency, traceability and digital control of food chain processes have been available for some time, yet are often deployed with a narrow focus on increasing productivity and reducing inputs (Garcia-Flores et al., 2019). Researchers have highlighted that technological trajectories are shaped by dominant ideologies and paradigms governing its use. Accordingly, in the case of systemic food waste reduction, which is in practice contrary to the interest of a productivity-oriented food industry (Kibler et al., 2018, p.271), technological innovations, and related physical infrastructure, need to be designed beyond the sole objective of productivity to enable new modes of production and consumption that are more sustainable (El Bilali and Allahyari, 2018, p.457).

Australia's dominant horticultural supply chain lacks established alternative niche solutions at an appropriate competitive scale (Dixon and Richards, 2016; McCarthy, 2014). Specifically acknowledging the respondents' calls for de-centralisation, transparency, flexibility and diversity, the transition challenge is to identify, experiment, create, and protect the growth of alternative socio-technical niche solutions and configurations, to achieve appropriate scale. Research has emphasised the crucial importance of "plural pathways and diverse knowledge" for sustainability transitions (Scoones et al., 2020, p.70), yet the current trajectory of horticulture is increasingly tracking towards convenient uniformity rather than sustainable diversity. Accordingly, support and protection needs to be withdrawn from dominant industry configurations resisting diversity, not only to improve supply chain resource efficiency, but also to mitigate waste-generating outcomes from the exercise of concentrated supermarket power. This support for alternative practices will have to stem from multi-stakeholder coalitions to mobilise and exert pressure on state regulators while also counteracting the prevailing government alliance with supermarkets. The transformation to diversity and transparency is likely to increase regime niche competition and conflict, which may be desirable as a condition to increase possible pathways for a more resilient, ethical and sustainable food chain.

4) Supply, Demand and Aggregate Resource Use

Considering the close and direct linkage between food surplus and waste creation and the proposed measures to monitor the "surplus footprint" of supply chains (Messner, Johnson and Richards, 2020), research has debated the overall benefits and economic impacts associated with reducing production as a measure of minimising surplus and waste (Koester, 2014; Rutten, 2013). While there is some evidence of supply restraint leading to significant reductions of resource use, for instance in terms of land use conversion (Rutten et al., 2013), the interviews did not favour any form of production restriction. Reducing production was regarded as unrealistic within the prevailing commercial reality of Australian horticulture.

With oversupply set to continue in the wider food chain, a popular response to food waste emerging from the research is processing and value-adding, essentially an approach aiming to turn large scale surplus and waste into a resource for innovative, high-value products. The research has presented an array of economic and operational difficulties to overcome the "waste miles" and other obstacles of operationalising waste as an economic resource. Moreover, research has highlighted the inherent inefficiency of repurposing surplus due to the irrecoverable resource inputs lost during production (Kibler et al., 2018; Vittuari et al., 2016). Moreover, there exists a "prevention paradox", which sees demand for surplus and waste increase once a nominal disposal solution exists (Messner, Richards, Johnson, 2020; Raak et al., 2017). The research findings consider value-adding an unlikely solution to large-scale surplus and waste. Rather, in the absence of sustainable and holistic transformations of current supply chains, value-adding and product innovation emerge as entirely new enterprises, likely to contribute to food chain surplus and new "waste chains" of their own.

The interviews have also pointed to measures of domestic and export demand stimulation to reduce surplus and waste. Respondents have cited the under-consumption of vegetables in Australia as additional waste generating factors. Supply and demand fluctuations, causing either shortage, surplus or food waste creation, were also described as recurring cycles within prevailing food chains. Demand

creation, without other interventions into the food chain, risks being an investment into future surplus and waste, reinforcing continuity of current supply chain practices rather than their transformation. Research has indicated that investments into both demand creation as well as product innovation, could adversely contribute to regime stability, rather than its sustainable transformation (Alkemade et al., 2011).

To determine whether demand creation and product innovation prevents food waste requires an understanding of "*direct and indirect resource use"* within an entire supply chain. Accordingly, "aggregate resource use appraisal and disclosure" could be regarded as a key approach complementing existing emission reporting. For instance, within the fossil fuel industry recent methodologies of "Scope 3" reporting have been aimed at disclosing emissions generated *directly and indirectly* through the use of fossil fuels, for example considering emissions from burning of coal, rather than only from mining coal (Downie and Stubbs, 2013). Focusing food waste responses onto conserving resources throughout the supply chain by monitoring aggregate resource use could be a useful starting point for developing regulatory mixes that better de-stabilise the existing regime while enabling sustainable niche approaches (Kivimaa and Kern, 2016, p.205).

This is not to say that interventions that focus on, for instance, value-adding to surplus or stimulating demand, are genuinely unable to prevent food waste. Rather, these interventions can be part of preventing food waste provided it is not their sole purpose to dispose of surplus. Reduced aggregate resource use can be achieved by product diversification, increased product versatility, and increased demand for such products, which together complement and enable other changes and interventions towards sustainable supply chains.

7 Conclusion

This research has advanced food waste as a systemic feature of food systems beyond mere individual responsibility. It has addressed the empirical and theoretical questions about which actors and

interactions are collectively responsible for food waste and how food waste prevention can contribute to sustainable food systems transitions.

This paper posits food waste as a feature of unsustainable value-creation and resource-use in a food chain dependent on overproduction, surplus and waste. Food waste prevention, accordingly, requires a transformed process of value creation decoupled from the systemic creation of waste. As a feature of unsustainable food chain practices, food waste creation cannot be prevented without transforming the practices it is inherently part of, such as using cosmetic standards, encouraging oversupply to decrease cost and allowing externalization of surplus and waste. For this reason, product innovations or demand stimulation are structurally unsuited to reduce food waste unless accompanied by profound transformations of supply chain practices.

Approaches to prevent food waste creation in food chains must be commensurate with the holistic nature of the problem. This research proposes a vision and objective of food waste prevention as reduction of aggregate rather than individual resource use. This differs from the prevailing paradigm of "resource efficiency" in that it considers *aggregate surplus and waste* along the whole supply chain, thereby preventing false claims of surplus and waste reduction assisted by externalisation to other points of the supply chain. As such, it seeks to *prevent* rather than *improve* unnecessary and unneeded resource use. Accordingly, food chain processes require a protocol of appraisal and disclosure of their contribution to "aggregate resource use" as a transition management principle.

In the highly dominant and deeply locked-in industry regime configuration the horticulture food chain represents, it will require explicit support for alternative practices, while at the same time withdrawing support from unsustainable practices perpetuated by the dominant industry regime. The current trajectory is headed for increased single-minded reliance on one model of food chain concentration and monopolisation, yet sustainability is more likely to arise from the availability of diverse, alternative and competitive pathways of development. Creating detailed agendas and action plans enabling availability

and feasibility of alternative sustainable solutions specifically suited to fresh food distribution will be an indispensable feature of a transformation to sustainability.

Lastly, this research proposes that interventions targeting the systemic prevention of food waste are by themselves transformations of fundamental characteristics of food systems towards greater sustainability. Such transformations will depend on the formation of coalitions of actors from within the dominant industry regime configuration as well as from outside. The coalitions must be able to transcend narrow industry elite interest and adopt a common vision and an ethic of shared responsibility rather than "limited liability" to restrict the "unlimited entitlement to use resources in order to produce waste" (Corvellec et al., 2018, p.18). Agency is, thus, expected to increasingly emerge from heterogenous regime, niche and landscape configurations as the environmental pressures keep building, dominant regime legitimacy keeps waning and diverse alternative visions and trajectories of systemic food waste prevention begin to crystallize.

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End of Research Papers

6. Summary of the Research Papers and Conclusion

The three papers represent a major part of the output of this research and presented various original contributions to food waste research, food system research and socio-technical theory. Paper One revealed fundamental dissonances in terms of the conception as well as the purpose of food waste prevention. Reviewing dominant prevailing narratives, discourses and approaches to food waste prevention, the review identified the concept of 'prevention paradox' that captures some of the practical, conceptual and ideological contradictions hampering effective food waste prevention. As the research progressively evolved from the early insights, the prevention paradox also matured to a clearer and perhaps more succinct conception: The prevention paradox arises from un-systemic and random efforts to resolve an essentially systemic and predictable problem, such as food waste.

Responding to the call for an understanding of food waste beyond waste management in Paper One, the systemic nature of food waste and its theoretical understanding was the focus of Paper Two, which proposed the concept of 'surplus-to-waste lock-in'. It addressed the particular sector of food system processes related to overproduction through an in-depth examination of system processes and their enabling mechanisms that give rise to waste creation. As such, Paper Two exposed the contiguous relationship between overproduction, surplus and waste. Surplus-to-waste lock-ins captured the congenital surplus generation of food chain processes as well as the largely inevitable demise of food surplus as waste. Specific system processes and industry characteristics in the horticulture supply chain, including prevailing practices of risk management, competition, growth governance, farming methods and supermarket power, are sustained by food chain lock-ins that do not only encourage surplus and waste creation, but even fundamentally depend on them. The empirical and theoretical evidence thus strongly supports that surplus prevention may be consdered a valid pathway of food waste prevention.

Following the conceptualisation and diagnosis presented in Paper Two, Paper Three was concerned with solutions and the way forward. This research theoretically identified and explained systemic food waste as a '"feature and symptom of food system lock-in into unsustainable practices of production and

consumption". Food waste prevention, accordingly, represents the initiatives and interventions that allow food chains to *escape lock-in* and to *transition* to more sustainable practices. Paper Three conceptualised possible transition pathways and measures by applying the theoretical perspective of socio-technical transitions, which supported a much broader and wider application and relevance of the research findings. Systemic food waste prevention was thus revealed as an enterprise of phasing out unsustainable practices while shifting support to more sustainable alternatives; of recognising the fundamental importance of diversity rather than uniformity of the infrastructures that support secure and sustainable food supply; of new concepts of competition based on transparency rather than manipulation; of recognising systemic food waste prevention as a shared social responsibility rather than a matter of selective efficiency. As such, systemic food waste prevention has been revealed as one important pathway to attain future food system sustainability.

The remaining sections of this thesis will present a summary of findings, conclusions, contributions and limitations of this study, as well as some direction for future research on systemic approaches of food waste prevention.

6.1 Key Findings

This research has offered a systemic perspective of food waste. Reviewing dominant discourses and approaches to food waste prevention globally, the conceptual analysis revealed a paradoxical economy of food waste prevention. The prevention paradox described how narrow approaches to food waste, such as ad-hoc approaches targeting a change of consumer behaviour or post-hoc approaches targeting the end-of-pipe management of existing waste material, have hampered efforts to achieve absolute reduction of food waste due to their failure to account for the effects of continuous systemic waste creation. The prevention paradox arises from the fundamental misconception, that food waste, which is systemically generated, can be reduced and prevented without addressing the systemic processes that created it in the first place. Consequently, this research proposed a systemic perspective describing and explaining food waste creation as a result of dominant practices and processes in the food supply chain,

thus establishing food waste as a phenomenon inherent to specific characteristics and features of food systems.

This study investigated food chain processes and practices related to overproduction and food surplus in primary production. Overproduction and surplus production have been revealed as prevalent features of the Australian horticulture supply chain and have been widely corroborated by research respondents. Due to conceptual and practical limitations of value recovery from surplus, including the dominant industry and government focus on producing more and the lack of relevant infrastructure and priority of waste prevention, food surplus commonly and inevitably turns to waste, a process this study has termed 'surplus-to-waste mechanics'. This research has demonstrated how the conceptual and practical limitations within the horticulture supply chain fail to prevent surplus from turning to waste, and rather reinforce the production of waste by enabling, amplifying and accelerating existing mechanisms of waste creation. Food surplus, to which overproduction is a significant contributor, has thus emerged as an indicator of impending food waste and, within industrial agrifood supply chains, must be recognised as broadly and practically equivalent to food waste. The findings from this research support the assertion in extant literature that surplus prevention is indeed a core approach of food waste prevention (Hic et al., 2016; Papargyropoulou et al., 2014; Pedersen et al., 2015).

The research supported a conclusion that large-scale on-farm surplus and waste primarily occur for the reason of supply chain management practices related to value creation, specifically the setting of quality standards and market prices. The interviews have given evidence of overproduction due to mechanisms inherent in supply chain practices simultaneously and asymmetrically promoting *value creation* at retail, specifically the dominant supermarket chains, and *waste creation* at primary production. Accordingly, food waste prevention depends fundamentally on transformations of food chain practices that depend on waste to create value, while generating more waste in the process. This model of value creation that externalises substantial and unsustainable amounts of resource waste has become locked-in over time and is widely condoned or even supported by industry and government as a dominant practice within the Australian horticulture supply chain. Any change to the prevailing unsustainable paradigm of supply

chain operation and value creation is thus likely to be met with strong resistance. Theoretically, technical-institutional lock-in and dominant regime resistance predict that dominant actors in the horticulture supply chain will promote end-of-pipe solutions to food waste as well as approaches of strong continuity and regime perpetuation rather than attempting to adapt fundamental food system processes. Herein lies the fundamental economic paradox of food waste prevention.

The existing horticulture supply chain model characterised by centralisation, concentration, and agricultural intensification together with its concomitant outcomes of a lack of product variety, freshness, locality, seasonality, and increased monoculture, long cold chain delivery, and dependence on waste creation is the dominant prevailing model of fresh food distribution. There is a lack of alternative supply chain models as well as forms of competition not solely focused on price and scale but other dimensions of delivering 'value'. Both limit the government's and industry's options to achieve a transformation to greater sustainability. The lack of diversity, alternative supply chain options and any feasible *back-up* option for existing 'ways of doing things' create a deep dependency of industry and policy makers on a single dominant model of fresh food supply fuelled by substantial and unsustainable resource waste. Accordingly, this systemic dependency extends to all people who depend on securely functioning food systems for their livelihood.

The research findings represent empirical data and theoretical explanations, which offer a number of original theoretical contributions to scholarship on food waste, food systems and socio-technical theory. The key theoretical contributions are highlighted in the next section.

6.2 Theoretical Contributions

6.2.1 Contributions to Theory of Systemic Food Waste and Food Systems

The 'system perspective' of food waste emerged from the review of food waste literature as the core empirical and theoretical knowledge gap, and represented the overarching research problem this thesis addressed. The study revealed how underlying mechanisms of competition, in-transparency, growth governance, and supermarket power contribute to systemic formation of surplus. The mechanisms causing continuous surplus creation are deeply embedded in prevailing paradigms of value creation and are also a driving force accelerating and reinforcing the transformation of surplus to waste. Systemic food waste has thus been identified conceptually as an *intrinsic and essential feature* of food system processes asymmetrically designed to create value at one stage of the supply chain by creating waste at another.

Related to the lack of in-depth knowledge on the system perspective of food waste, this research furthermore pursued the additional objective to identify and elaborate a *theoretical understanding of the significance* of food waste for food systems. To support broader theorising of food waste within food systems, the perspective of socio-technical transitions facilitated a conceptualisation of food waste as a symptom of deeply locked-in supply chains and food systems. Accordingly, food waste is symptomatic of unsustainable practices that stabilise the system and resist profound transformations to more sustainable practices of production and consumption. As food waste creation is imbedded in unsustainable locked-in supply chain practices and processes, food waste prevention therefore consists of interventions and adaptations that break and escape the deep-seated lock-ins of food chain and food system processes that create unsustainable levels of waste. As such, food waste prevention, via the transformation of waste dependent value creation processes will not only reduce food waste but is also expected to increase overall food chain sustainability. Correspondingly, sustainable transformations of food chains not primarily targeting food waste are likely to contribute to food waste reduction as a

concomitant outcome. The prevention of systemic food waste as a transformation of waste creating processes thus emerges as a distinct pathway of transitions to food system sustainability.

By positioning systemic food waste within theoretical framework of socio-technical transitions, this thesis extended transition theory to the fields of food system studies and food waste research. As such, it presented conceptual pathways to bridging micro, meso and macro levels of analysis of systemic food waste (see Figure 2). The conceptualisation of systemic food waste and food waste prevention represents a significant and original contribution to two important bodies of scholarship, food waste research as well as food systems research.

As another distinct contribution this thesis has developed concepts and constructs grounded in a socio-technical perspective and designed to facilitate further discourse and theorising of systemic food waste. Specifically, this research has increased the *conceptual vocabulary* enabling analysis and theorising of food waste across different scales and levels. Key examples of concepts proposed in the research papers include the 'prevention paradox', which describes the contradictory and idiosyncratic outcomes from approaches to food waste prevention that fail to account for the systemic nature of the problem. 'Surplus-to-waste mechanics' and 'Surplus-waste lock-in' describe how the system characteristics and mechanisms driving systemic surplus formation implicitly prevent value recovery from surplus, normally consigning it to waste instead. The concepts of 'aggregate resource use' and 'surplus footprint' are transition management principles that address surplus as a symptom of waste creation and support surplus reduction in whole supply chains as a target of food waste prevention. Lastly, 'food waste transitions' as a concept describe the nature of systemic food waste prevention as an important pathway of transitions to food system sustainability. These concepts emerged from the empirical and theoretical inquiry of this thesis, which was grounded in the theory of socio-technical lock-in and transition management. As such, they provide an analytical frame that helps render visible 'blockages' in the food system that thwart efforts to prevent food waste. Moreover, they illuminate key aspects and insights into the systemic nature of food waste and present stepping-stones for further theorising of systemic food waste prevention.

6.2.2 Contributions to Socio-technical Transition Theory

Sustainability transition research has grown into a substantial body of scholarship, which is periodically reviewed and directed by the Sustainability Transition Research Network (STRN). This section presents some specific contributions of this thesis to some research priorities proposed in the most recent update of the 'sustainability transition research agenda' (Köhler et al., 2019). The research agenda has highlighted a shortfall of studies on food systems compared to other large-scale social systems such as energy and transportation (Hinrichs, 2014; Markard et al., 2012). By providing a stepping-stone to future theorising on food waste from a combined socio-technical and food system perspective, this thesis makes a contribution to literature on socio-technical transition studies of food systems. Furthermore, the transition agenda has highlighted a shortage of studies that address whole industries rather than relying on single case studies, as well as transition studies in different spatial and geographic contexts, which this extension to the Australian horticulture industry contributes to (El Bilali, 2019; p.361).

This thesis also contributes to lock-in analysis and theory. Research has highlighted the lack of in-depth explanation of *specific mechanisms* that cause lock-in to become manifest within the multi-level perspective of socio-technical theory. Accordingly, the detailed analysis of 'surplus-to-waste waste lock-ins', especially the identified specific types of lock-in grounded in empirical data from the context of the Australian horticulture supply chain, contribute to socio-technical theory by increasing understanding of "specific aspects of regime persistence" as well as "preconditions for transitions" (Klitkou et al., 2015, p.23). Furthermore, in relation to escaping lock-in, this thesis strengthens the empirical base of transition management theorising by extending the concepts of 'destabilisation' and 'phasing-out' to the Australian horticulture industry. This represents a contribution to another important research priority included in the sustainability transition research network agenda (Köhler 2019; p.11).

The Sustainability Transition Research Agenda (Köhler et al., 2019, p.6) has highlighted the use of "suitable alternative social research approaches" as a desirable direction of further theory development. In this regard, this thesis makes a contribution to Socio-technical Theory by highlighting the epistemological compatibility of the alternative and complementary theoretical framework of Social Domain Theory, specifically its congruence with the multi-level perspective of socio-technical transition theory (see Figure 2). This research has demonstrated how Social Domain Theory can make a contribution to transition research owing to its capabilities to build theory from empirical case data through the multi-layered framework of social domains (see section 2.2.2). Social Domain theory offers practical research approaches to bridge between analytical aspects of individual agency and structural and contextual landscape influences as well as to enhance the 'reach' of meso-level theory across different units and levels of analysis such as micro-macro or generic-particular. Within this research, Social Domain Theory provided an example of how the framework of domain analysis was able to apprehend the multi-faceted influences of broader social contexts on human agency, generating system concepts and typologies for further interpretation from a Socio-technical Multi-level Perspective. This two-tier approach could be a methodological blueprint useful across a wider range of sustainability problems, not only food waste.

6.3 Practical Recommendations

Apart from research findings and distinct theoretical contributions, this study is also able to make a number of practical recommendations.

1) The research interviews have linked food waste creation to specific food chain practices, which must be transformed in order to achieve food waste prevention. Cosmetic standards applied by supermarkets as private standards of product appearance and have been widely recognised as unfair trade practices and must be either phased out or subjected to fair and transparent governance. Cosmetic standards, combined with other related supply chain practices such as lack of product diversity, purely price-based competition and lack of alternative mass distribution channels contribute to significant surplus and waste

generation in primary production. This waste generation accounts for about one third of food waste in Australia and, while it is substantial, it is largely invisible and tacitly accepted. The practice of letting private business setting standards that promote their own interest while causing large scale waste at other points of the supply chain needs to be subjected to scrutiny and addressed with resolve if food waste is to be genuinely prevented. The problem of supermarket power is not unique to Australia as various other developed countries face similar challenges to regulate supermarket power. Considering the significant impacts of market power on waste creation, this is a prime space for government or civil society organisations supported by government to re-engage with industry regulation rather than condoning subsidisation of narrow industry benefits at the expense of social and public goods.

2) Competition focused solely on price currently rewards waste generation in the supply chain, as large amounts of waste at the production stage paradoxically correspond with lower cost for supermarkets and consumers. As long as waste creation is thus incentivised it must be expected to persist. Two important points are suggested: The externalisation of waste subsidises low purchasing prices for supermarkets, which distorts real cost, competition and accountability. Waste externalisation as a subsidy to supermarkets therefore needs to be addressed and either penalised or phased-out in order to reduce food waste as well as to achieve more transparent value creation processes. Secondly, competition on low price alone disregards and dis-incentivises vital food system outcomes related to more sustainable production and consumption. Once competition becomes focused on other criteria rather than merely low cost, and once invisible cost distortions that favour unsustainable products and services are exposed and removed, businesses and households will be able to choose sustainable rather than unsustainable products and services as they may present better overall *value* for individuals as well as society. Sustainability transition governance will have to create market based or regulatory mechanisms to make incentives transparent and aligned with broader social goals, including food waste prevention, and remove cost subsidies from unsustainable practices. To improve the chances of real progress and success such transformative governance approaches will have to be legitimised by government or, less likely, supported by voluntary commitments of industry and supermarkets.

3) Product innovation, re-use and value-adding have been commonly seen as measures to prevent surplus food from going to waste. The research findings suggest that product focused prevention measures are unlikely to succeed in reducing large scale surplus and waste unless accompanied by substantial adaptation of the supply chain and available infrastructure. Without supply chain adaptation surplus management, value adding and other types of end-of-pipe solutions are likely to perpetuate surplus formation and result in an increase of aggregate resource use and waste. Any form of product innovation proposed as a solution to surplus and waste must therefore be accompanied by adaptations of infrastructure and supply chain practices to reduce food waste. The transformation toward surplus-reducing supply chain adaptation can be achieved through industry incentives, regulation, various forms of fiscal transition support and government grants specifically aiming at sustainability transformations.

4) The systemic nature of food waste creation that is embedded in food system processes and practices necessitates holistic responses along the whole supply chain. For instance, prevention of food waste due to cosmetic standards must engage with multiple supply chain stages to be effective. The systemic nature of the problem requires systemic rather than ad-hoc or post-hoc responses. Ad-hoc responses include for instance, the 'business case' of food waste prevention. Based on the findings of this research, which support similar conclusions in extant literature (FAO, 2019a), it appears unlikely that individual business can make a wider impact on food waste in supply chains. A case in point are supermarkets, whose standards and business practices cause very substantial waste at various stages of the supply chain, and who appear very successful in waste prevention from a viewpoint of the business case. Within the Australian food supply chains, retail is close to zero in terms of waste generation at their own supply chain stage (Arcadis, 2019). For as long as it is acceptable for businesses to divert and avert waste to other points of the supply chain, progress in food waste prevention will be elusive. Rather, commensurate with the systemic nature of the problem and its recognition as a *common goods* problem, systemic approaches to governing food waste, i.e. approaches addressing the whole industry, supply chain, economy or even society, might be indispensable to achieve absolute reductions. In this regard this research suggested a transparent disclosure and monitoring of aggregate surplus and waste in supply chains, which as a standard allows to evaluate individual and independent initiatives in

terms of their contribution to overall aggregate surplus and waste. This recommendation follows the principle of shared responsibility for waste generation as well as its prevention.

5) The findings suggest that diversity rather than the uniformity of a dominant and increasingly concentrated production and distribution model may be an important prerequisite for sustainable food chains. Fresh food supply may benefit from diverse approaches such as short localised, supply chains, box schemes, consumer cooperatives supported by technology, traceability of origins, principles of freshness, locality and seasonality. Many concepts for reform are available in the literature, (e.g. see Galli and Brunori, 2013 and Priefer et al., 2016). Irrespective of what the alternatives may be, the key recommendation is that multiple coexisting options for mass distribution of fresh food are more likely to deliver sustainability than adherence to one single dominant model (see Scoones et al., 2020). To create this crucial diversity in the fresh food supply chain, in terms of infrastructure as well as products and services, government and policy makers must specifically support alternative models and practices by withdrawing systemic support for prevailing dominant supply chain actors and unsustainable practices and enabling and promoting alternatives to reach competitive and appropriate scale.

6) This thesis has highlighted the close relationship between surplus and waste conceptualised as ‘surplus-to-waste lock-in’. This concept describes the sequence, or the journey of food from the field, via surplus to its final destination as food waste. The research findings have revealed the deep relationships between surplus and waste and the underlying social and technical mechanics that support and enable this connection. Secondly, surplus-to-waste mechanics also emphasise the systemic nature of this transition. It describes the specific industry settings and characteristics that determine what and how much is grown, the social and technical processes and dominant practices that necessitate and reinforce overproduction, and the specific material and ideological resources that represent an industry infrastructure supporting surplus production but inadequate for surplus and waste prevention.

Accordingly, surplus as a proxy for food waste, is something that needs to be monitored in order to facilitate food waste prevention. This thesis has proposed surplus as part of a broader problem of unsustainable

resource use and recommended as a primary approach monitoring of aggregate resource use, which includes the surplus footprint of food system processes and activities. Two key aspects have been highlighted: Firstly, the primary focus of monitoring is transparency and disclosure. Direct and indirect impacts of resource use must be included into measurement protocols and surplus and waste impacts need to be part of statutory disclosure by corporations, organisations and institutions. As an example for a possible disclosure approach this thesis has cited disclosure of indirect green house gas emissions, also referred to as “scope 3 emissions in the fossil fuel industry (Downie and Stubbs, 2013). Secondly, measurement protocols have to apprehend aggregate surplus and waste impacts throughout an entire value chain rather than at any distinct point of the supply chain. This is critical as resource use in terms of surplus and waste creation has been an essential component of the value creation process and substantially subsidised by the negative externalities related to surplus and waste production. Moreover, the value creation process has been fundamentally dependent on externalising or diverting waste to other parts of the supply chain, for instance from supermarkets to producers and households. The system perspective recommends that surplus and waste should be apprehended and disclosed as an aggregate.

6.4 Limitations and Direction for Future Research

Limitations of this research chiefly arise from methodological choices and the demarcation of the subject matter. The key limitations discussed in this section derive from the way the research was designed and how this research could have been done differently, thereby offering suggestions and direction for future research. The field of systemic food waste (prevention) research is very recent and emerging and many of the aspects listed below could contribute to a much deeper understanding of systemic food waste within food systems.

This study defined a specific scope of research with clear boundaries. In terms of the industry under research, this study decided to focus on the Australian horticulture supply chain, i.e. fruit and vegetable growing, rather than broader categories like ‘fresh food’, which includes for example fresh meat, dairy, seafood, or even ‘food’ as a general category including processed, manufactured, preserved, and

packaged foods. These larger categories of food are not only important from a food systems perspective but even more so from a food waste perspective. As such the empirical, and perhaps also some of the theoretical findings, may specifically relate to challenges in fresh and perishable produce supply chains, and not necessarily in a supply chain of processed and more durable foods.

Another important limitation related to the choice of research subject concerns the segmentation of the supply chain stage under study. As outlined in the section on data sampling the upstream industries, whose activities bear upon the production phase of horticulture, were excluded from the scope of this study. In terms of downstream, only wholesaling, as a hybrid category between production and distribution was included. This study took a perspective of systemic impacts and influences on the processes and practices at a specific stage of the supply chain, i.e. primary production. A systemic view could also choose to study integrated processes along the whole supply chain, from seedling via production and retail into households, including a focus on the interfaces between supply chain stages. For example, due to the significant importance of supermarkets in the horticulture supply chain as well as the consumer end, such an approach could offer complementary and important perspectives, which are beyond the scope of a ‘single stage study’.

This study of systemic food waste has linked food system processes to food waste creation. In order to ensure appropriate focus of the study some specific food system processes had to be selected to the exclusion of others. As a growing body of food waste research has highlighted overproduction as a potential cause of food waste and suggested further research, this thesis has chosen food system processes specifically related to overproduction and surplus creation. To narrow the subject matter further this research has predominantly focused on processes and practices of overproduction in primary production and at the interface to wholesale and retail. Beyond specific practices at the growing and processing stage, other aspects leading to overproduction, such as legislation, regulation, policy, incentives, horticultural finance and investment, technology adoption and agronomy, as well as the industry structure and consumer market characteristics need to be investigated further as part of understanding waste generating processes and technical-institutional lock-in.

While this study limited its scope to overproduction, food systems offer various other types of systemic processes and practices that contribute to food waste creation. For instance, drawing on the framework of food system outcomes by Ingram et al. (2013, p.237), production activities are subsumed under food system processes related to 'availability' of food. Systemic food waste could also be studied by investigating processes related to 'utilisation' of food, for instance posing the question, how the systemic choice of what food to produce is related to food waste. Also processes related to the aspect of 'access' could be a fruitful field of inquiry regarding food waste creation, for instance by asking for whom food systems produce food. Systemic food waste creation and prevention are indeed deeply interlinked with fundamental food system processes that need further investigation in relation to food waste creation as well as to the extent such processes are subject to lock-in and transition resistance.

The particular choice of the limited sector and the limited range of food system processes related to overproduction was, to an extent, dictated by the methodological necessity to focus the research objective and research questions. As such, this research provided insights in relation to surplus food that is produced only to be wasted, which raises ethical questions of natural resource use and other avoidable environmental and social harms due to surplus and waste. While, on the basis of extant literature and institutional publications, resource use is recognised as an important dimension of sustainable production and consumption (FAO, 2019a; UNEP, 2017), it is equally important to recognise that sustainable development represents a much broader and infinitely more complex vision than the limited concept of 'reduced resource use' is able to apprehend. As such, sustainability has been described in terms of key boundaries of *maximum and minimum resource use*, depending on which aspect of sustainable development resource use is related to. In this regard, researchers have advanced the concepts of "sustainable consumption corridors" (Di Giulio and Fuchs, 2014) and "doughnut economics" (Raworth, 2012) to illustrate distributional aspects of resource use that enable *the good life*. For the purpose of describing limitations of this study, it has to be borne in mind that this research is focused on a specific, component or aspect of sustainable development, i.e. the amount of natural resource use dedicated to waste creation rather than human consumption. It is not focused on the complex interrelations between

natural resource use and other dimensions of sustainable development or even on a holistic concept of 'sustainability' itself. While this may be viewed as a key limitation of this study, it also highlights how this research, by offering a systemic theoretical understanding of food waste, represents a building block for further theorising of holistic and systemic approaches to sustainable development.

Limitations also arise from the use of theory. To conceptualise findings and to draw conclusions, this thesis draws on two theoretical frameworks, Social Domain Theory as well as Socio-technical Transition Theory. The methodology section (see 2.2) has revealed how both approaches represent a type of a mid-range theory, i.e. theory connected closely to research data and choosing a meso-level of analysis. As such this theoretical approach sits between 'grand theory', for example political economy or food regime theory, and theories of individual agency, such as planned behaviour or social practice approaches. This thesis does not adopt macro or micro perspectives, rather, the conceptual vocabulary offered by this thesis contributes to bridging the gap between micro and macro levels of analysis and provides a basis for further theorising of systemic food waste using theoretical frameworks on different levels.

As a mid range theory the socio-technical multi-level perspective (see 1.2) has been critiqued as favouring bottom up approaches and regarding the landscape level, or macro-level, as a mere "residual category" rather than a key analytical level (Geels, 2010). Also this thesis, while briefly touching upon some aspects of human geography and matters of broader social scale, space and context (Coenen and Truffer, 2012; Murphy, 2015), focused very much on the industry regime level to understand waste creation and solutions. It is an important issue for a theoretical perspective of this kind to choose the appropriate level of empirical and theoretical analysis. At the same time, the choice of analytical level also inherently limits the scope and application of the study.

As outlined by Grin et al. (2010) the socio-technical multi-level perspective requires a very substantial amount of data and in-depth empirical analysis in order to provide robust explanations of the subject matter. The multi-level perspective has been criticised for offering a too simplistic theoretical vocabulary that may be easily applied to complex and multidimensional subject matters thus forcing certain

conclusions on the data without a sufficient underlying empirical grounding and analysis (Geels, 2010, 2011). This resulting potential *superficiality* of analysis, or even simple 'reification' of regime and niche, is a critique that may be leveled more generally against evolutionary theories or approaches relying on explanatory inference. In regard to this thesis, the aspects of technical-institutional complex as well as lock-in rely on very specific data derived from this research program. To fully apprehend regime, niche and landscape dynamics broader and more comprehensive data would be very helpful, including for instance multiple complementary data sources. Furthermore, also complementary methodological approaches such evolutionary-historic analysis, document analysis and comprehensive in-depth case studies could be helpful to strengthen the empirical base of the study. Explanation based on socio-technical theory, requires a very deep and comprehensive knowledge of the subject matter to which the contribution of this thesis naturally had to be limited.

Table 15 summarises some of the key limitations and corresponding opportunities for future research that are suggested on the basis of the findings and conclusions from this thesis. The suggested further research may contribute to a more comprehensive understanding of systemic food waste creation in various sectors of the food system and facilitate theory building on the significance of food waste within transitions to food system sustainability.

Table 15: Limitations and Future Research

Limitations of Thesis:	Current Thesis	Future Research	
Sample:	*Horticulture*	Meat, dairy, seafood	Processed / dry goods
Process / Characteristics:	*Production stage / overproduction*	Whole process along supply chain	Production planning; transparency; technology
Food System Service/Outcome:	*Availability*	Access	Utilisation
Agency:	*Growers / Agents / initial processing*	Manufacturing, retail, food service, consumer	Government, civil society actors; institutions
Research Problems Theory / Perspective:	*Food Waste Socio-technical Lock-In*	Research Problems: "food security"; "resilience", "hunger", "nutrition and health"	Theories: Food Regime Theory; Economic Theory; Political Economy; Technical Innovation Systems;

In sum, based on the contributions and limitations of the study, further research, specifically on the subject matter food waste, is suggested in the areas of 1) a complete assessment and mapping of all food system settings implicated in food waste creation, 2) waste creation from food system processes related to other sectors such as 'food utilisation' and 'food access', and more broadly food security; 3) studies tracing processes of systemic waste creation along the whole supply chain; 4) in-depth case studies of industries, firms or institutions; 5) transparency and disclosure protocols for aggregate resource use tracking unneeded surplus in supply chains and 6) the study of resource use *impacts*, rather than only *amounts*, within overall sustainable development, especially in relation to other important goals of sustainable development. As highlighted by the literature review, the knowledge on systemic food waste and its relevance for sustainable food systems is still very limited and many opportunities exist for contributions in this very new, emerging and rewarding field of scholarship.

6.5 Concluding Remarks

The arc of this research began with the conceptual dissonances of dominant approaches of food waste prevention and the economic paradox inherent in prevailing approaches to food waste prevention. It identified the failure to account for the systemic nature of food waste as the key source of paradoxical phenomena related to food waste prevention. The research concludes now, having revealed systemic food waste prevention, i.e. interventions into systemic food waste creation processes, as a pathway to overall food system sustainability.

This study has identified and explained, empirically and theoretically, the phenomenon of systemic food waste. As an outcome as well as an intrinsic feature of self-reinforcing food system processes, food waste emerged as a symptom and indicator of food system processes locked-in into unsustainable practices of overproduction and surplus creation. Subjected to system lock-in, food waste is created by unsustainable processes and practices, and is shaping these practices in return. Food waste prevention,

accordingly, is the adaptation and transformation of food system processes towards more sustainable practices of production and consumption.

This thesis has also explored and discussed aspects of food surplus and waste prevention that are related to agency and the wherewithal to effect change. Growers emerged as disempowered, industry as pre-occupied with growth and productivity, supermarkets as deeply invested in surplus and waste creation. Transitions are thus unlikely to happen, unless key private actors, such as industry and supermarkets, elect to voluntarily commit to absolute reductions of aggregate food surplus and waste in food chains, or unless a broader shift in governance philosophy sees the strong technical-institutional alignment of government with industry undergo a profound re-appraisal. This thesis has highlighted government's unique capabilities to safeguard public goods when private interests are unwilling or unable to do so and these unique capabilities might have to be called upon if food waste prevention is to be pursued with some degree of priority and urgency. Most crucially, having established the fundamental connection of food waste prevention to food system sustainability, future efforts to prevent food waste should no longer elect to ignore the systemic processes of waste creation, if a real and absolute reduction and prevention of food waste is their genuinely desired goal.

7. References

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