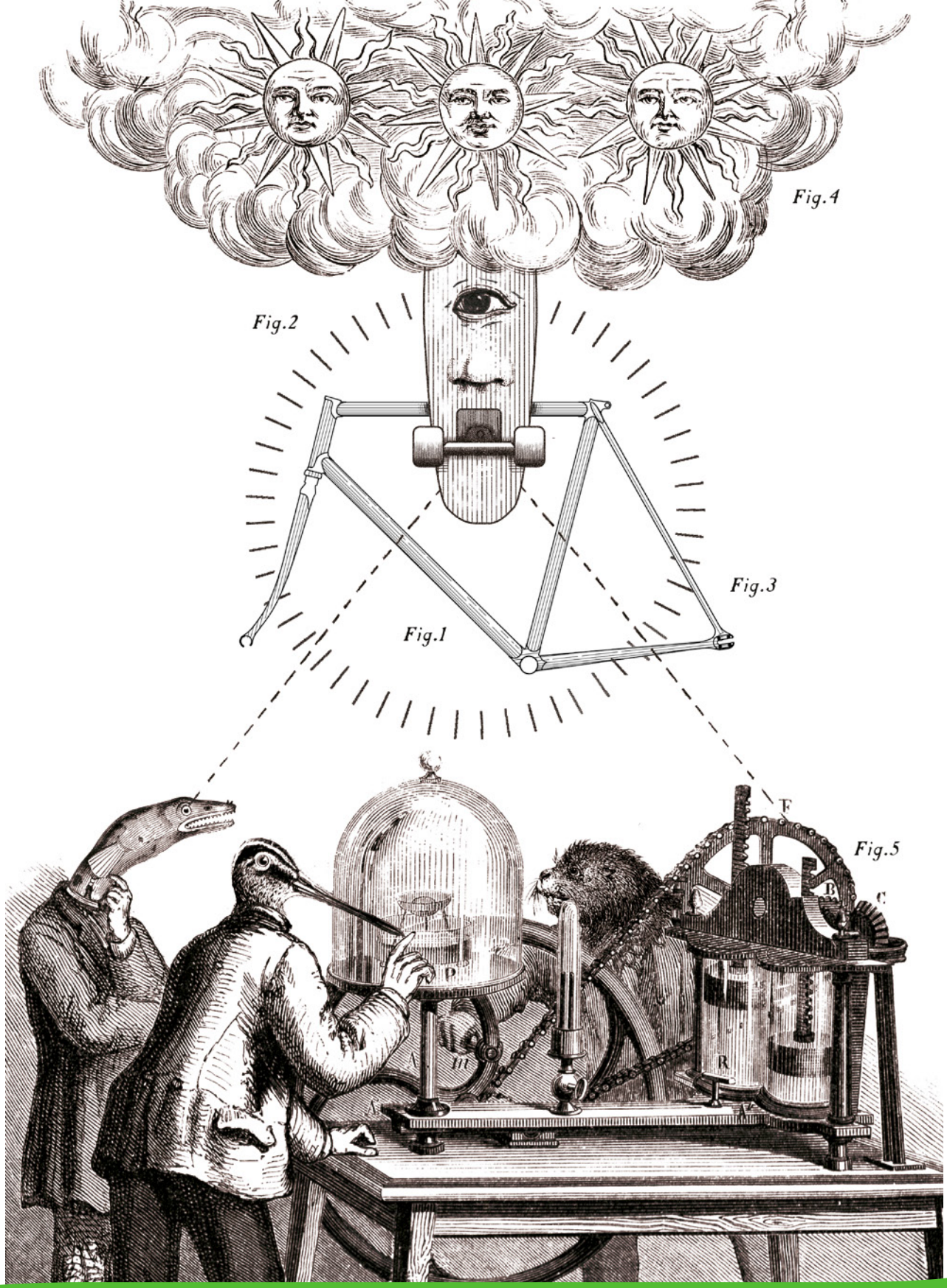

Public Agricultural Research in an Era of Transformation: The Challenge of Agri-Food System Innovation

CGIAR Independent Science and Partnership Council

CSIRO

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Andy Hall
Jeroen Dijkman

Public Agricultural Research in an Era of Transformation: The Challenge of Agri-Food System Innovation

March 2019

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EXECUTIVE SUMMARY

The United Nations 2030 Agenda for Sustainable Development and the Sustainable Development Goals (SDGs) reflect a growing consensus that the central challenge society faces is the need to break the path dependencies of development pathways rooted in 20th-century values and priorities, and to transition to more sustainable and inclusive trajectories of development. At the heart of this agenda is a call not only to improve production and consumption systems, but also to transform the fundamental characteristics of these systems to tackle the underlying causes of inequity and unsustainability. The urgent need for transformation defines the current and future development agenda of the 21st century, and the agriculture and food sectors are pivotal to meeting it.

Research, technology and innovation are key ingredients in transformation. It is, however, the way that transformation reframes innovation and the implications of this for public agricultural research organisations, particularly the CGIAR, that are the focus of this study.

A number of recent studies of current and future agriculture and food trends and challenges have argued that component technology and piecemeal innovation will be inadequate to ensure sustainability and that inclusion concerns must be integrated throughout the agriculture and food sectors. The concept of an agri-food system has emerged as a way to understand and work with these interconnected elements. Agri-food system innovation will involve rethinking how research and innovation are deployed to transform the social, economic and environmental performance of the agriculture and food system. Despite the advent of these new ideas, much of the current narrative remains stuck in a productionist and technology-centric perspective determined by linear and component change logics. This contributes to agri-food systems being locked into incremental change that is out of step with transformation ambitions.

The study's review of current thinking on innovation and the sustainable development agenda argues that this agenda represents a progressive broadening of the problem framing from firm to sector to society and that this broadening challenges the analytical framing of innovation. In particular, the understanding of transformation as the transition to new societal conditions – or new socio-technical regimes, as these are referred to in recent literature – has caused a shift from *innovation systems* to *system innovation* as an analytical and policy framing. Innovation systems here refer to a framing concerned with the networks and institutional and policy conditions that enable the development and use of goods and services. In contrast, system innovation refers to a framing concerned with the reconfiguring and realignment of a diverse array of societal elements – social, political, technical, institutional and policy – for the realisation of societal outcomes such as sustainable and inclusive growth. Whereas an innovation systems framing primarily concerns the level of innovation activity, a system innovation framing primarily concerns the direction of innovation activity and its alignment to desired societal functions.

System innovation is apparent in a number of perspectives that have been developed to help understand how path dependencies and system changes can be managed in the energy, transport and manufacturing sectors. These include the following:

Sustainability transitions. These are long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable alternatives.

Strategic niche management. This approach focuses on investigating the introduction of sustainable technologies using societal experiments (e.g. pilot plants, demonstration plants) in pursuit of improving interactions among the elements of a socio-technical system and boosting its efficiency in achieving its objectives.

Multi-level perspective (MLP). This heuristic aims at explaining the process of substitution of a technological paradigm. MLP distinguishes three perspectives: landscape, regime and niche. The landscape represents the broader picture of socioeconomic systems. The regime consists of the established technological paradigm. A radical alternative has to grow in a niche before it is able to compete with the established paradigm.

Transition management (TM). This is a cyclical process model that consists of four components: (i) structuring the sustainability problem and establishing the transition arena; (ii) developing a transition agenda, i.e. a vision of sustainable development and possible transition pathways; (iii) establishing and carrying out transition experiments and mobilizing the resulting transition networks; and (iv) monitoring, evaluating and learning lessons from the experiments, and making adjustments in the vision, agenda and coalition

These perspectives highlight transformation as a dynamic process of transition to a system with new societal functions. These also draw attention to the long-term, multi-level, multi-phase and multi-actor nature of the transformation process. A simple heuristic visualises the transition processes through four phases: pre-development, take-off, acceleration and stabilisation at a new level or relapse. These are illustrated by examples from the emergence of electric vehicles and wind power in Denmark. The examples reveal the critical role of periphery players and the emergence of new coalitions of interest around viable sustainability options. In addition, the examples show that efforts to bring about transformations towards sustainability are deeply political and contested because different actors will stand to gain or lose.

This conceptualisation of transformation as system innovation is explored in the agriculture and food sector through an analysis of 16 case studies. The case studies are of two distinct types. The first are historical accounts of transformation and transition processes unfolding over many years, usually in a particular subsector or industry. The second are "snapshot" examples of a particular set of activities that are often indicative of bigger transitions taking place in the background. The case studies do not all document transformation in the sense of the system innovation perspectives outlined above. They do, however, provide critical insights on factors that both support and hinder transformation.

The historical case studies show how, technology, regulation, coalitions of interest, private sector activity and market forces have been drivers at different points in the transition process. These cases do not suggest that any one of these drivers on its own causes transition and transformation. Rather, they suggest that these drivers play an important role at specific points in time and are often a response to changing contexts and values. Socio-political dynamics are an important part of many of the transition processes. These take a number of forms such as, for example, peripheral groups joining forces to advocate for policy and regulatory change or changes in incumbent industry practice. Another notable feature of the historical case studies is the specific effort made to address the perverse consequences of transformation, particularly the environmental and social externalities.

The snapshot case studies describe a defined set of actions in the context of a wider change process that may or may not be gaining momentum. In some cases, this involved business pioneers pursuing sustainability and/or inclusive activities. This cannot be described as a transformation of the

agri-food system, it does illustrate how the growing backdrop of sustainability awareness is increasing companies' interest in trying new business models and the feasibility of doing so. A number of the snapshot case studies deal with the development and promotion of specific technologies. These technologies cannot be described as transformational but instead are either a response to emerging market and social demands or an anticipated demand of a sustainable development pathway.

A key message from both the historical and the snapshot case studies is that there is an interconnected set of changes across multiple levels of agri-food systems involved in transition and transformation processes. Component innovation, like the snapshot case studies, is important, but it is the longer-term complex of processes and factors that bring about deep changes or system innovations that will underpin the emergence of sustainable agri-food systems. While it remains important that both the public and private sectors invest in "snapshot" interventions, this needs to be conceived as part of a much broader agenda of change in which research and technology development are only one part.

While the above patterns are strongly akin to the concepts and perspectives on innovation developed in other sectors, there are also a number of notable differences. These include the importance of social acceptability and social licence due to society's intimate relationship with food compared with other types of goods and services, the dependence on biological systems and the unique forms of regulation that this requires, the importance of agri-food systems to large numbers of poor people and food security, the unpredictable disruption in agri-food systems caused by technological advances that emerge in other sectors, and the weak capacity of the agri-food system to shift to more sustainable forms of governance.

ISSUES, PROCESSES AND APPROACHES THAT ARE BECOMING MORE IMPORTANT FOR PUBLIC AGRICULTURAL RESEARCH ORGANISATIONS

Transformation and the sustainable development agenda are creating a different context for all organisations involved in innovation and change processes. Some of these concerns relate to the nature of transition and transformation processes and its dynamics, its governance and its stakeholders. Other concerns relate to society's increasing engagement in decisions around the direction of societal change. Public agricultural research organisations are going to need to pay increased attention to the following issues:

- Transformation as a deeply political process;
- The increasing power of societies to articulate and leverage aspirations and patterns of societal acceptance ;
- Negotiated processes used to determine future development pathways;
- Engagement with pioneer activity to leverage niche sustainability experiments;
- The increasing prominence of complexity in sustainable development problem framing; and
- The directionality of innovation.

THE DIMENSIONS OF PUBLIC AGRICULTURAL RESEARCH THAT ARE BECOMING MORE PROBLEMATIC

Transformation and the sustainable development agenda are making a number of dimensions of agricultural research practice increasingly problematic. In part, this relates to the diminishing relevance of some approaches in the light of the sustainability agenda. In other cases, it relates to problematic as-

sumptions that either no longer hold true or that have not been supported with evidence and critically assessed.

- Innovation systems as an analytical and policy framework is not able to deal with directionality;
- Scaling logic not adapted to system innovation;
- Unrealistic assumptions about the role of the private sector;
- Misleading technology-centric narratives of transformation;
- Funding cycles poorly aligned to the transformational agenda;
- The absence of an evidence base for many agri-food system transformation stories; and
- Incremental biases in current evaluation and impact assessment traditions.

NAVIGATING TRANSFORMATION AND DIRECTIONALITY IN AGRI-FOOD SYSTEMS

Based on its insights, this study develops an agri-food system innovation framework to help understand different transformation situations and to help make decisions about courses of action that can advance transformation and sustainability transitions.

The core of the framework is the recognition of the relationship between four innovation environments related to transformation.

Incremental innovation. This is an environment that reproduces and maintains an existing innovation trajectory. It is characterised by optimization within the existing system, with limited agri-food systems adaptation.

Incumbent innovation-driven transformation. This is an environment that generates a new innovation trajectory and system innovation that transforms the production and consumption system. It is characterised by the dominance of economic growth as the key performance indicator.

Experimental discontinuity. This is an environment that allows space for numerous niche innovations and for the piloting of new production and consumption systems, generally by peripheral players. These niches seed a discontinuity in the dominant innovation trajectory.

Sustainability transitions. This is an environment that supports a discontinuous shift to a new innovation trajectory and production and consumption system. The environment is characterised by values, incentives and regulations that balance economic, social and environmental performance.

The framework provides a lens for public agricultural research organisations to reveal where current activities fit into the transformation landscape.

IMPLICATIONS FOR THE CGIAR

The CGIAR already has a strong directionality narrative flagged by an explicit ambition to contribute to the SDGs. The agri-food system innovation perspective on transformation does, however, raise issues that all public agricultural research organisations including the CGIAR need to pay attention to. This study suggests that the CGIAR could consider the development of four new narratives that frame critical areas of its activities and role:

- A new scaling and impact narrative that adopts an agri-food system innovation perspective;
- A new partnership and value network narrative that emphasises commitment to advancing the sustainable development agenda;
- A new social licence narrative that proactively addresses issues of social acceptability and the need to create a platform to host these discussions; and

- A new science narrative that accommodates transdisciplinarity and the role of social and systems sciences in the innovation process.

The process of elaborating these narratives through consultations and strategic conversations with stakeholders, including donors, could be a critical step for the CGIAR in garnering the financial and operational support for a central role in the emerging transformation agenda.

A VISION OF THE CGIAR AS A CHAMPION OF DIRECTIONALITY OF INNOVATION

The current global development agenda is about transformational change and in particular the sustainability transitions of agri-food systems and of society as a whole. Today, there is no international player explicitly acting as the custodian of an international science agenda that supports the transformational ambitions of agricultural and food sectors and that works to ensure the directionality of agri-food system innovation. The CGIAR could occupy this role. Such a role would align with its core values and strategic intent. It would re-emphasis its globally important role and in doing so reinvigorate political and financial support. It would also help build new capacities at a time when global development is at a critical point of inflection and in need of proactive investments in public goods.

REPORT AUTHORS

Andy Hall
Research Leader, Agri-food Systems Innovation, Agriculture and Global Change Program,
Agriculture and Food, CSIRO, Black Mountain, Canberra, Australia

Jeroen Dijkman
Senior Agricultural Research Officer, CGIAR Independent Science and Partnership Council Secretariat, Rome, Italy

LIST OF ACRONYMS

AR4D	agricultural research for development
BMP	best management practices
CARB	California Air Resources Board
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EADD	East Africa Dairy Development
ECF	East Coast Fever
FMD	foot and mouth disease
GM	General Motors
GMO	genetically modified organism
GR	Golden Rice
HPAI	highly pathogenic avian influenza
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDE	International Development Enterprises
ISPC	CGIAR Independent Science and Partnership Council
ITM	infection and treatment
ML	megalitre
MLP	multi-level perspective
MSC	Marine Stewardship Council
NGO	non-governmental organisation
OECD	Organisation for Economic Co-operation and Development
OFSP	orange-fleshed sweet potato
R&D	research and development
SDGs	Sustainable Development Goals
SNM	strategic niche management
TM	transition management
VAD	vitamin A deficiency
WRI	World Resources Institute
WUE	water use efficiency

1 PUBLIC AGRICULTURAL RESEARCH IN AN ERA OF TRANSFORMATION

1.1 INTRODUCTION

Transformation is *the* defining feature of the contemporary global development agenda. The Sustainable Development Goals (SDGs) articulate this feature and call for the transformation of society. In part, this is a recognition of the failure of current development trajectories to deliver across the full spectrum of economic growth, social inclusion and environmental sustainability objectives. Critically, transformation is not about treating symptoms, but about addressing the root causes of inequality and environmental degradation. These perspectives are part of the growing consensus that the central challenge society faces is the need to break the path dependencies of development pathways rooted in 20th-century values and priorities and to transition to more sustainable and inclusive trajectories of development.

In this new era of transformation, science and innovation will be critical. This reality raises many questions about how to reframe research and innovation and how to harness innovation for sustainable growth. Nowhere are these questions more pressing than in the agri-food sector. Food security, human nutrition and health, the livelihoods of rural communities, responses to climate change and economic growth remain intimately connected to the sector. Yet the agri-food sector has a history of growth that has often been environmentally damaging and sometimes socially divisive. It is no exaggeration to say that the success of the SDGs as a whole depends on finding ways to use research and innovation to transform agri-food systems towards more productive but also more sustainable and socially inclusive pathways.

The CGIAR[1] and other public agricultural research organisations are expected to be critical to wider efforts to tackle the SDGs. However, thought needs to be given to how to adapt research and innovation essential activities to the necessities of the era. Technological breakthroughs will be undoubtedly be essential. It is increasingly recognized, however, that deploying new technology will require deep changes in agri-food systems if more sustainable and socially responsible growth is to be achieved. This recognition represents a complex set of interrelated technological, social, and policy and political changes. The CGIAR and other public agricultural research organisations need to consider how to engage with this dynamic and reposition themselves in a way that best contributes to the aspirations for inclusive and sustainable agri-food systems.

[1] The CGIAR (formerly the Consultative Group for International Agricultural Research) is a global partnership that unites organisations engaged in research for a food-secure future. CGIAR research is dedicated to reducing rural poverty, increasing food security, improving human health and nutrition and ensuring sustainable management of natural resources.

1.2 ABOUT THIS REPORT

The purpose of this report is to provide some of the groundwork in answering the question of how the CGIAR system and other public agricultural research organisations should adapt and respond to an era of transformation framed by the SDGs. It does this by exploring the way in which this transformation agenda reframes agricultural research and innovation.

Building on an earlier study of multi-stakeholder partnership and the SDGs (ISPC, 2015), this report draws together the results of a two-year study conducted by CSIRO and the CGIAR ISPC Secretariat on innovation and transformation of agri-food systems. The study's activities also included a system-wide dialogue on the reframing of the common narrative on agri-food system innovation, supported by two multi-stakeholder workshops held at CSIRO, Canberra, in December 2016 and at the International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, in June 2017 (CSIRO and CGIAR ISPC Secretariat, 2016, 2017).

The core of the work is a set of 16 in-depth case studies that offer historical accounts of agricultural innovation processes. The case studies are used to illustrate transformation processes, highlighting key features. These accounts are used to develop insights into the role of research and innovation in transformational processes and to frame a broader discussion on the implications for public agricultural research organisations and specifically the CGIAR.

To place the case study analyses in context, this report includes a review of current thinking and debates on innovation and transformation. The literature on these topics has grown rapidly in recent years, particularly in relation to sustainability transitions. The central message from this literature is that the sustainable development agenda is bringing about a reframing of innovation concepts and policy, placing greater attention on system innovation and the direction and purpose of innovation trajectories. This reframing is at the heart of the shift that public agricultural research organisations are going to need to deal with, and this theme informs the analysis throughout the study.

The report is organised as follows:
Chapter 2 provides additional detail on the transformational challenges in agri-food systems. The third chapter provides an overview of key concepts and themes in the innovation and transformation literature. Chapter 4 presents an analysis of the 16 case studies to illustrate how transformation takes place in the agri-food sector. The fifth chapter draws on the case studies and the literature review to highlight the issues, processes and approaches that are becoming more important to public agricultural research organisations and the dimensions of agricultural research practice that are becoming increasingly problematic in the light of the characteristics of agri-food system transformation. It then develops an agri-food system innovation framework to help in understanding different transformation situations and to help make decisions about courses of action that can advance transformation and sustainability transitions. The final chapter discusses implications for the CGIAR. It proposes that the CGIAR develop four new narratives – on scaling, partnership, social license and science – to frame critical areas of its activities and role. It suggests that the process of elaborating these narratives through consultations and strategic conversations with stakeholders, including donors, could be a critical step in garnering financial and operational support for the CGIAR's role in the emerging transformation agenda. The study concludes by emphasizing that this offers the CGIAR an important opportunity to position itself as a global champion of the sustainability transition in agri-food systems.

2 THE SDGS, INNOVATION AND THE NEW TRANSFORMATION AGENDA

The SDGs represent a turning point with profound implications for all countries. The goals are ambitious and explicitly couched in the language of transformation. The critical agenda of the SDGs is the emphasis on creating significant improvement in the social and environmental performance of production and consumption systems, in addition to economic growth ambitions. Enabling shifts along these different performance axes implies the need for fundamentally different consumption and production systems and will require wide-ranging technical, institutional and policy change.

What makes the SDGs such a break from the past is therefore not just the placing of inclusiveness and sustainability at core of the global development agenda. The key difference is the emphasis on transforming production and consumption systems as the pathway to achieving its ambitious targets. This is an explicit recognition that while global development trajectories of the past have advanced economic growth, they have been less effective in achieving social development and environmental sustainability. The SDGs are thus a call to break these path dependencies and to shift to new and more sustainable trajectories of innovation and development.

It is in this way that the transformation agenda of the SDGs starts to reframe innovation. It draws attention to the need for deep changes in production and consumption systems – system innovation – as a prerequisite, or at least a companion to innovation in component parts of the systems such as individual technologies or new practices. Whereas component innovation the deployment of individual technologies, policies and institutional designs, system innovation involves reforming or adapting an interlocking set of policies, values, practices and technologies, power and politics that shape innovation directions and priorities.

The remainder of this chapter describes the transformation context of agriculture and food domains. It also introduces the concept of an agri-food system as a way of mapping the scope of innovation needed to make the step change improvements towards sustainability implied by the SDGs.

2.1 AGRICULTURE, FOOD AND THE SDG CHALLENGE

The agriculture and food domains are central to a number of SDGs: SDG 1 (No poverty), SDG 2 (Zero hunger), SDG 3 (Good health); SDG 12 (Responsible consumption) and SDG

13 (Protection for the planet), but the domains are equally closely interlinked with the other 12 (FAO, 2018).

A raft of recent papers, reports and analyses (e.g. FAO, 2017, 2018; FAO *et al*. 2018; Caron *et al.*, 2018; Development Initiatives, 2018; WRI, 2018; Willet *et al.*, 2019; Swinburn *et al.*, 2019) all examine current and future agriculture and food trends and challenges. Although the reports examine different aspects of agri-food systems, their conclusions all highlight that global food security is in jeopardy, owing to mounting pressures on natural resources and climate change, both of which threaten the sustainability of food systems at large. Planetary boundaries may well be surpassed if current trends continue. And whether the reports emphasize the need for profound changes in dietary habits (Willet *et al.*, 2019; Swinburn *et al.*, 2019) or a 22-item "menu for a sustainable food future" (WRI, 2018), one thing is clear: all responses will require fundamental changes in the way societies produce and consume food. The rallying cry of these and similar earlier reports (see, e.g., World Bank, 2012; 2017a; 2017b; OECD, 2011; WEF, 2018) is explicit. The call is not only for agri-food system transformation at scale, but also for drastic change in the ***direction*** of transformation, toward delivering a balanced set of social, economic and environmental outcomes.

Recent analysis by Reardon *et al.* (2017, 2018) and others (e.g., IPES-Food, 2017; www.eatforum.org) provide a comprehensive picture of currently ongoing global food system transformation. These studies conceptualise the transformation process as a progression along a pathway from traditional through transitional to modern, with the latter being characterisd by the consolidation of various food system segments, such as the rise of supermarkets in retail. The analyses presented suggest that starting from the 1980s, progressive waves of food system transformation have taken place, starting in East Asia and Latin America. More recently, transformation has also reached sub-Saharan Africa (Battersby, 2017; Allen *et al.*, 2018), which along with South Asia is currently in a transitional phase (Shamsi *et al.*, 2018).

Other analyses also highlight that the ongoing changes in food systems are generally accompanied by greater vertical integration and greater capital intensification, causing smallholder producers to lose out (FAO, 2017; FAO *et al*., 2018; Caron *et al*., 2018; Development Initiatives, 2018; WRI, 2018; Willet *et al*., 2019; Swinburn *et al*., 2019). These studies highlight the related need to rethink food system governance to redirect food systems towards a more efficient, inclusive and resilient pathway. Reardon *et al.* (2017, 2018) paint a slightly more mixed picture on the impact of food system transformation, suggesting that more stringent market demands can "narrow" the winners to those smallholders who have the resources to respond. The off-farm employment associated with transformation, however, has often provided sector exit options through the creation of jobs with low barriers to entry.

What is equally telling about the current food system transformation is the often leading role of the private sector in driving innovation and change and setting direction (Reardon *et al.*, 2017, 2018; Caron *et al.*, 2018; FAO, 2017; Willet *et al.*, 2019; Swinburn *et al.*, 2019). Increasingly, the urban market, the food industry firms that mediate access to the urban market, input supply chains, and agri-business firms that determine the development of input supply chains set the market incentives and conditions for the affordability and profitability of new farm technologies, and thus their adoption (Reardon *et al.*, 2017, 2018; IPES-Food, 2017; Caron *et al.*, 2018; WRI, 2018; Willet *et al.*, 2019; www.eatforum.org). This situation raises question about the appropriateness of food systems governance arrangements at a time when the environmental and social performance of food systems needs particular attention.

A recurrent feature of the debates highlighted above is the recognition that the challenges facing agriculture and food systems in setting new directions are not isolatable problems, but rather a set of interlocking issues and drivers (FAO, 2017, 2018; FAO *et al*., 2018; Caron *et al.*, 2018; Development Initiatives, 2018; WRI, 2018; Willet *et al.*, 2019; Swinburn *et al.*, 2019). One proposed way to bet-

ter deal with this is the adoption of the idea of an agri-food system: a descriptive metaphor for the interconnected elements of food production and consumption, and the defining social, environmental and political context in which these sit.

Although this term has been widely adopted in much of the current discourse, a definition has yet to stabilize (Box 1). It can, however, be thought of as containing the following main elements:

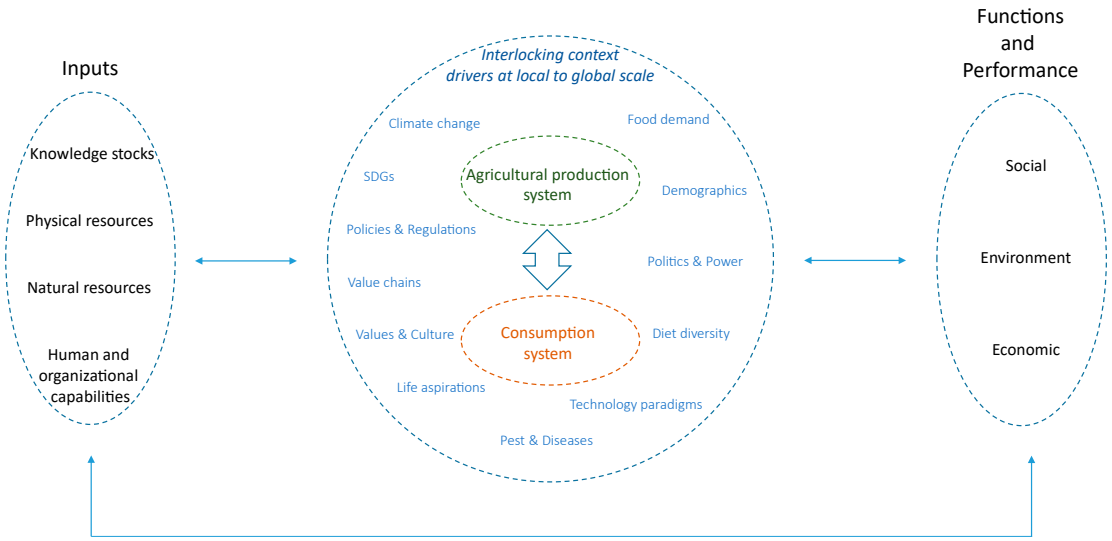
- Production domain: all matter needed to produce agricultural products;
- Consumption domain: all matter needed to process, transform, distribute and consume agricultural products;
- Conditioning context: all matter that shapes the direction and priorities of the production and consumption domains;
- Inputs: all matter needed for production and consumption to take place; and
- Functionality: the social, economic and environmental performance/services provided (Figure 1).

BOX 1. AGRI-FOOD SYSTEM DEFINITIONS

An agri-food system may be simply defined as the combination of activities and institutions around the production and consumption of a particular food item. These systems are complex, operating simultaneously at multiple levels of scale (from global to local) and time (particularly with respect to the timing of outcomes). Agri-food system activities include production, storage, processing, wholesaling and consumption. In addition to these activities, an agri-food system also includes a complex "web of institutional and regulatory frameworks that influence those systems" (IPES, 2015).

An agri-food system has also been defined as "an interconnected web of activities, resources and people that extends across all domains involved in providing human nourishment and sustaining health, including production, processing, packaging, distribution, marketing, consumption and disposal of food. The organisation of agri-food systems reflects and responds to social, cultural, political, economic, health and environmental conditions and can be identified at multiple scales, from a household kitchen to a city, county, state or nation" (Grubinger ***et al.***, 2010).

Figure 1. Agri-food systems



Source: Authors.

2.2 AGRI-FOOD SYSTEM INNOVATION: REFRAMING THE CONVERSATION

The notion of an agri-food system innovation refers to the need to stimulate system changes in food system, as a route to addressing new societal functions such as inclusion and sustainability. Focusing attention on food system innovation and advancing this agenda is difficult because it challenges many entrenched views on the nature of innovation and perceptions about agri-food system performance that shape policy and practice. Thompson *et al.* (2007) and Thompson and Scoones (2009) raised similar concerns a decade ago. They suggested that vested interests in the sector and a food and agricultural policy tradition informed by "productionist" science and technology, modernization and stages of growth narratives have locked agriculture and food systems into transformation trajectories that have failed to provide sustainable outcomes for many poor people. They argue that because such views provide little insight into the dynamic character of agri-food systems, they prevent agriculture and food policy from enabling different pathways of development and from helping society navigate complex and unpredictable change processes.

Thomson and Scoones (2009) and Smith *et al.* (2010) go on to argue that change in agri-food systems is deeply embedded within a wide range of human activity. It involves powerful interest groups and is dominated by a path-dependent trajectory of innovation that historically has delivered food and prosperity but often at an environmental and social cost. In considering how to address this, Meynard *et al.* (2017), Caron *et al.* (2018), Willet *et al.* (2019) and Swinburn *et al.* (2019) all point out that innovation cannot tackle sustainability by dealing with farming systems or food consumption issues in isolation. Instead, sustainability needs to be addressed in a coupled, systemic way that recognizes how the dynamics of the interlocking elements of an agri-food system reinforce existing innovation pathways. Altering these dynamics requires innovation in the system itself and not just in its component parts.

Enabling the innovation process that supports such transformational change is becoming a major challenge in policy formulation (Schot and Steinmueller, 2016; FAO, 2017). This is not just an issue for national governments seeking to develop new policy tools and prioritized investments. It is also raises questions about the responsibilities of the public, private, and civil society sectors and, in the context of agri-food systems, the role of public agricultural research organisations in the transformation agenda.

Despite the evidence that innovation is a systemic, messy and long-term process, with complex unpredictable cause-effect relationships that operate across scales, it is a more simple narrative that prevails and continues to inform much policy formulation and public investment. In particular, it is the view of innovation as a predictable process with simple cause-effect relationships that persists and continues to frame how many development stakeholders engage with the transformation of agri-food systems. Coalition building to bring in new framings, perspectives, analysis and evidence on innovation in agri-food systems will thus be essential to changing the dominant narrative of change. A reframed change narrative would help public agricultural research organisations to find a new *modus operandi*, help set more realistic expectations, and help unlock new courses of action aligned to global development ambitions (Glover and Poole, 2019).

Previously published analysis as part of the current study (Hall *et al.*, 2016) and the outcomes of the accompanying CGIAR system-wide dialogue on the reframing of the common narrative on agri-food system innovation (e.g., CSIRO and CGIAR ISPC Secretariat, 2016, 2017) have suggested that the prevailing simplistic narrative underpins a set of approaches, policies and investment patterns that lock agri-food systems into incremental rather than transformational innovation pathways. This plays out in a number of ways in the priorities and practices that shape the portfolios of public agricultural research.

- *Research funding*: Funding modalities reinforce priorities towards short-term gains quick wins *versus* long-term gains, legacy *versus* blue sky, farmer-centric *versus* agricultural production and consumption systems-centric, and market failure *versus* precompetitive, skewing research outputs towards system optimization;

- *Evaluation and impact assessment*: Unrealistic impact expectations, combined with the persistence of historical key performance indicators and economic performance framing, continuesthe weak learning orientation towards improving the research and innovation process;

- *Capabilities and skills*: The slow replacement of historical research capacities continues the path dependency of legacy research, which is often out of step with rapidly evolving trends in agricultural production and consumption systems; and

- *Partnership*: Continued reliance on partnerships and networks that worked well in the past might not be fit for future purpose (ISPC, 2015; Hall *et al.*, 2016).

Understanding transformation as agri-food system innovation therefore raises new challenges for the CGIAR and other public agricultural research organisations. Not only does it underline the complexity of innovation processes involved, but it also highlights the need for considerable institutional innovation to realign the contribution of public agricultural research organisations towards transformational processes.

The next chapter explores in more detail the way transformation and the sustainable development agenda reframe innovation and further emphasizes the importance of agri-food system innovation in achieving the SDGs.

3 REFRAMING INNOVATION FOR SUSTAINABLE DEVELOPMENT

3.1 INTRODUCTION

In recent years, there has been explosive growth in research on the topic of transformation and its conceptualisation as a dynamic process of transition to production, consumption and governance systems with sustainability characteristics. This area of research and the increasing prominence of the sustainable development agenda have also started to impinge on the framing and conceptualisation of innovation. Smith *et al.* (2010) argue that the sustainable development agenda represents a progressive broadening of the problem framing from firm to sector to the whole of society and that this has challenged the analytical framing of innovation. This broader problem framing has moved through successive stages from the need for clean, sustainable technology, to the need for innovation systems producing clean, sustainable goods and services, to the need for societal conditions that allow new and more sustainable development pathways to be pursued. This way of thinking about innovation and change is at the heart of the transformation agenda enshrined in the SDGs.

Indeed, it is this idea of the transition to new societal conditions – or socio-technical regimes, as these are referred to – that has created a distinct point of departure in the conceptual framing of innovation. At the risk of oversimplification, this is a shift from *innovation systems* to *system innovation* as an analytical and policy framing. Innovation system here refers to a framing concerned with the networks and institutional and policy conditions that enable the development and promotion of goods and services in the market. In contrast, system innovation refers to a framing concerned with reconfiguring and realigning a diverse array of societal elements – social, political, technical, institutional and policy – for the realisation of societal functions such as sustainable and inclusive growth. Markets are an important part of this broader picture, but so too are other institutions (Smith *et al.*, 2010). Whereas an innovation systems framing primarily concerns the level of innovation activity, a system innovation framing primary concerns the direction of innovation activity and its alignment with desired societal functions.

As this chapter will explain, system innovation is a critical process in the transition to reconfigured production, consumption and governance systems. System innovation is therefore at the core of the transformation agenda, and arguably is its signature characteristic. By the same argument, innovation systems perspectives need to be superseded by a paradigm of innovation where much greater emphasis is placed on the purpose to which innovation is directed (directionality), the coalitions of interests needed to drive societal-level changes,

and the need to recognise that technological change is embedded in multi-level processes of social acceptance, enabling capabilities, and policy and regulatory conditions.

The purpose of this chapter is to provide an introduction and overview of the key concepts and themes associated with the shift from innovation systems to system innovation perspectives that are emerging alongside the transformation agenda. It draws on an internal resource document that reviewed, but also looked beyond, agriculture-related discourse to explore how generic analytical and problem framing are emerging that have relevance for the agricultural sector and agricultural research and innovation in particular.[2]

3.2 CORE CONCEPTS

3.2.1 Innovation and innovation systems

Contemporary policy and analytical framings on innovation are based on an understanding of innovation as *novelty in action* rather than invention, where change involves adoption and spread of technology, but also adoption and spread of practices, routines, processes and policies that create new economic or social value. Innovation is viewed as the key driver of the adaptation and evolution of economic systems where the action of diverse agents both brings new ideas into use and also creates the conditions and capabilities for the use of those ideas. This view of innovation sits within the tradition of evolutionary economic theory that views economic development as process of continuous learning and change rather than a process of optimization. It highlights the ways change processes take place across the interconnected scales and domains of human activity.

This systems view of innovation has formed the foundation for a range of policy and conceptual perspectives dealing with economic development over the past few decades. Perhaps the most notable of these stemmed from the observation that the economic success of some countries is related to configurations of processes and players that connect public and private sectors and particularly research and development (R&D) organizations and enterprises and that these connections underpin enhanced innovation performance. Freeman's (1988) and later Lundvall's (1992) observations of these "national systems of innovation" laid the foundation for *innovation systems* as a globally significant analytical and economic policy framing. Initially developed as a policy and capacity-building framework for industrial sectors in OECD economies, the concept of innovation systems is increasingly being used in relation to agricultural development in the global South (World Bank, 2006, 2012) and has been adopted as a national economic planning framework in increasing numbers of emerging economies (Cirera and Maloney, 2017).

Understanding innovation in this way marked an important shift not only in analytical perspectives, but also in economic policy. It moved the focus from technology and innovation inputs like R&D to understanding the whole process through which ideas emerge and are put into use and the wide array of social, institutional and policy factors that enable or hinder this more broadly conceived notion of the innovation process. In particular, it drew attention to the importance of the interacting networks of agents needed to enable information flows in an economy and the habits, practices and policies that determine how effectively these agents develop and spread new products and services in the market. In the context of agriculture in emerging economies, Hall (2012) argues,

> *The power of the innovation systems idea is that it helps see beyond innovation as a single point of intervention and to focus on multiple entry points, such as research, education, business, infrastructure, institutional arrangements, and the policy environment. Most importantly, it points to the interconnected nature of the change and innovation process. This refers to the links between different organisations associated with a particular focal area, but also to the technological innovation,*

[2] The internal review undertaken by Kate Andrews, Visiting Fellow, Fenner School of Environment & Society, ANU College of Science, Canberra, Australia, is available from the authors on request.

organisational innovation, and institutional and policy innovations that work hand in hand and need to be tackled as a whole rather than in a piecemeal manner.

Yet despite the fact that the innovation system perspective has been valuable in ushering in some much-needed new thinking, the changing global development agenda is starting to challenge this perspective, particularly in the global South. Challenges include the following:

- It emphasizes on private sector-led innovation at a time when inclusive and sustainable growth are as important as overall economic performance;
- It is primarily concerned with understanding and improving the level of innovation rather than paying attention to its direction and its alignment with desirable societal functions;
- The institutional, policy and social settings of many of the societal challenges now faced are qualitatively more complex than the industrial development origins of the concept; and
- It neglects the political economy of the innovation process and the need to better balance different stakeholder agendas in innovation direction choices and priorities.

As outlined in the introduction to this chapter, Smith *et al.* (2010) argue that it is the broadening of the problem framing associated with the increasing prominence of the sustainable development agenda that has led to the search for innovation perspectives beyond innovation systems. A related perspective is the concern not just for the speed of innovation but also for its direction (Stirling *et al.*, 2007). Calls for ways to improve the directionality of innovation have become more prominent. For example, Schot and Steinmueller (2016) call for a paradigm of transformational innovation that they refer to as Innovation 3.0, a new policy perspective that will embed sustainability and social inclusion objectives while retaining the power and relevance of policy instruments from both the innovation systems (Innovation 2.0) and the technology transfer (Innovation 1.0) paradigms. (See also discussion in Box 2.)

It is within this context that analytical and policy framings are starting to switch attention from innovation systems to system innovation. The next section looks at the system innovation perspective within the framing of sustainability transitions.

BOX 2. RESPONSIBLE INNOVATION

One response to calls to give greater attention to the directionality of innovation is an approach referred to as responsible innovation. Von Schomberg (2011) describes a research and innovation process that takes into account effects and potential impacts on the environment and society and provides the following definition:

"Responsible Research and Innovation is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products, in order to allow a proper embedding of scientific and technological advances in our society."

3.2.2 Transitions and transformation

Long before the current interest in transformational change, Freeman (1982) highlighted that certain forms of innovation are more profound and pervasive in their scope and impact. Specifically, those innovations with the most profound and pervasive impact involve "deep systems changes". Freeman's typology differentiates transformative or system innovation from other types of innovation as follows:

- Incremental innovation or systems optimisation: This refers to incremental improvement of existing products and services or incremental improvement of value-chain efficiencies that deliver marginal social, economic and environmental impact within specific production systems and value chains.

- Radical innovation: This consists of technological and/or market "step jumps" or discontinuities that open up new economic, social and environmental impact opportunities in a specific subsector or market sector and open up new opportunities for incremental innovation.

- Transformative innovation. This refers to deep systems changes, underpinned by a broad-based consensus that significantly advances the economic, social and environmental frontiers of a sector as a whole and that opens up opportunities for new waves of radical and incremental innovation.

Freeman's (1982) category of transformative innovation encapsulates what is now referred to as system innovation, defined by the OECD (2015) as "a form of innovation that fulfils societal functions. And that entails changes in both the components and the architecture of systems" (see Box 3 for further elaboration of the features of system innovation). The core argument of the system innovation perspective (and the socio-technology regimes perspective discussed below) is that for technology to have value, it needs to be an embedded part of a system of use. This system comprises capabilities, practices, rules, values, infrastructure and policies. While new technologies are often viewed as transformational, it is the innovation of the system itself that is transformational, as it allows the deployment of new technology. Thus, the defining feature is not the embedded technology per se (although this may be emblematic of the transformation; for example, high-yielding varieties in the Green Revolution). Rather, the defining feature is the system innovation that enables pervasive use of new technology and that supports a new direction or trajectory of innovation and development.

As discussed above, the explicit understanding of the systems dimension of technological change and innovation has been a key element of innovation systems perspectives. The system innovation perspective builds and extends upon innovation systems approaches by applying key systems insights to the study of the direction of technological change (OECD, 2015). The perspective acknowledges the multiple levels within which transitions to new systems configurations occur and places a renewed emphasis on meeting societal demands as key performance criteria.

BOX 3. CHARACTERISTICS OF SYSTEMS INNOVATION

Systems innovation fulfils societal functions and entails changes in both the components and the architecture of systems. It is characterized by three main features:

1. Knowledge and technical capabilities that either disrupt existing competencies and technologies or complement them, resulting in new combinations. An example could be the case of synthetic biology and its potential to revolutionise industrial and biological processes but which is limited owing to regulatory barriers or incoherence between research funding policies, product and safety regulations, and technical and market risks or consumer acceptance.

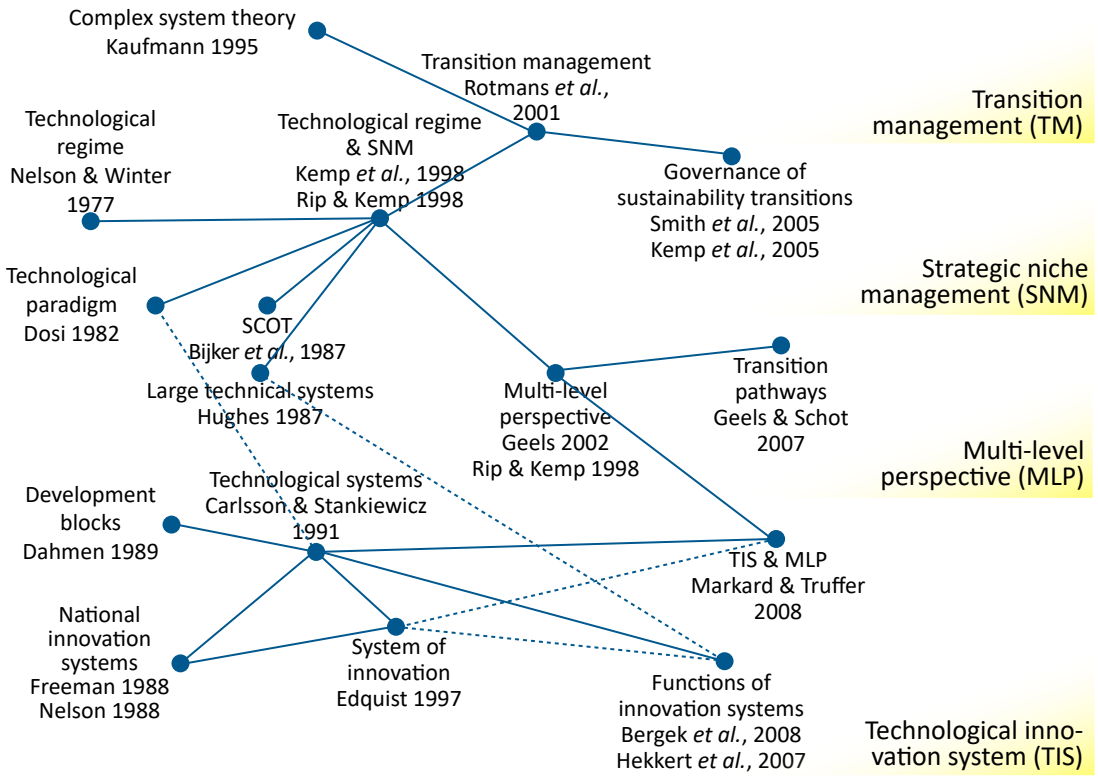
2. Fundamental changes in consumer practices and markets. Digitisation and "the internet of things" are examples of change brought about by changing consumer behaviour and technology that results in companies' potential loss of control over consumers, increased competition, and the need to engage digitally with suppliers, partners, employees and consumers/citizens.

3. Novel types of infrastructures, institutional rules, skill sets, and other elements, including policy and culture. An example could be the case of modern mobility systems for people (i.e. e-mobility) that are evolving owing to underlying changes in technology, ownership structure, consumer preferences and related changes in energy systems and their linkages to other systems.

Source: OECD (2015).

The essence of the systems innovation perspective has, for the last two decades, implicitly been at the heart of what is now referred to as the sustainability transformation or sustainability transitions literature. Markard *et al.* (2012) explain how the current interest in this topic has built on diverse bodies of thinking on innovation and change over the past four decades or so (Figure 2). This broad domain of research has greatly advanced thinking about the direction of technological change and how path dependencies are broken and major society-level changes take place. The Markard *et al.* (2012) typology highlights four key perspectives: (i) transition management (Rotmans *et al.*, 2007), (ii) strategic niche management (Kemp *et al.*, 1998), (iii) the multi-level perspective (Geels, 2002), and (iv) technological innovation systems (see definitions in Box 4).There are now many variants and elaborations of these widely discussed and cited perspectives.

Figure 2. Map of key contributions and core research strands in the field of sustainability transition studies



Source: Markard *et al.*, 2012.

BOX 4. DEFINITIONS IN THE FIELD OF SUSTAINABILITY TRANSITION STUDIES

Sustainability transitions. Long-term, multi-dimensional and fundamental transformation processes through which established socio-technical systems shift to more sustainable alternatives (Markard *et al.*, 2012).

Strategic niche management. An approach that focuses on investigating the experimental introduction of sustainable technologies using societal experiments (e.g., pilot plants, demonstration plants) in technology introduction in pursuit of improving interactions among the elements of a socio-technical system and its efficiency in achieving its objectives. (https://www.igi-global.com/dictionary/strategic-niche-management/28400)

Multi-level perspective (MLP). A heuristic that aims at explaining the process of substitution of a technological paradigm. MLP distinguishes three perspectives: landscape, regime and niche. The landscape represents the broader socioeconomic system, and the regime consists of the established technological paradigm. A radical alternative has to grow in a niche before it is able to compete with the established paradigm. (https://www.igi-global.com/dictionary/multi-level-perspective-mlp/54201)

Lock-ins. Lock-in can be defined as positive feedbacks or increasing returns to the adoption of a selected technology (Arthur, 1994; Unruh, 2000, 2002). As a result, incumbent technologies have a distinct advantage over new entrants, not because they are necessarily better but because they are more widely used and diffused. Positive feedback mechanisms decrease production costs and create additional benefits for users. A stable incumbent regime is the outcome of various lock-in processes, and it favours incremental as opposed to radical innovation (Klitkou *et al.*, 2015). Lock-ins lead to patterns innovation that reproduce existing socio-technical regimes.

Distinctions between reproduction, transformation and transition. Reproduction refers to incremental change along existing trajectories. Transformation refers to a change in the direction of trajectories related to a change in rules that guide innovative action. Transition refers to a discontinuous shift to a new trajectory and system (Geels and Kemp, 2007).

Transition management (TM). A cyclical process model that consists of four components: (i) structuring the sustainability problem and establishing the transition arena; (ii) developing a transition agenda, i.e., a vision of sustainable development and deriving possible transition pathways; (iii) establishing and carrying out transition experiments and mobilizing the resulting transition networks; and (iv) monitoring, evaluating and learning lessons from the experiments and making adjustments in the vision, agenda and coalition (Loorbach, 2010; Rotmans and Loorbach, 2009).

At the risk of oversimplifying the very broad literature on this topic, the core idea is an explanation of why trajectories of development, powered by innovation, have a high degree of path dependency and lock-ins (see Box 4 for a definition of lock-in) – and thus why changing the direction of development is so difficult. It is argued that technology, practices, policies, politics and power, institutional arrangements, infrastructure and societal values interlock to define a dominant socio-technical regime. Regimes act as an enabling "system of use" for particular clusters of technologies or technological trajectories (for example, the crop varieties and agro-chemicals associated with high-input, intensive agriculture). These systems of use encompass the social and economic structures and institutions – capabilities, markets, regulation, practices and norms – that emerge alongside new technology and are adapted to enabling its use. This phenomenon is also referred to as the social embedding of technology. At the same time, socio-technological regimes also include the conditions and incentives

fuelling the direction of innovation that reinforces and extends existing technological trajectories. These conditions and incentives relate to the patterns of stakeholding and governance in the regime and have strong political economy dimensions.

A classic example is the historical path dependency in energy and transport systems. Historically the dominant socio-technological regime has supported oil-based combustion engine-powered vehicles through a fuel supply infrastructure, pricing and taxation policies as well as an associated research, engineering and innovation capacity tailored to fossil fuel-based energy, all supported by powerful vested interests in the oil and automotive sector. The introduction of alternative energy systems, therefore, not only requires technological innovation such as hydrogen-based fuel cell technology (which has already been invented), but also requires a whole set of related changes, including political will, to usher in a new socio-technical regime based around this technology (Mytelka, 2003).

Smith *et al.*, (2010) describe the elements of the socio-technical regime of the modern food system as

> *physical inputs, plant-breeding techniques, pesticides, harvesting technologies, transport and logistics, food processing, cooking technology, the social elements that give these artefacts meaning and purpose—such as prevailing attitudes towards farming, ideas about soil health and nutritional food, official agricultural policy and price-support mechanisms, organised interests, the structure of food retailing, shifting trends in food consumption, and other social considerations, including concern about long-term environmental sustainability.*

While socio-technological regimes can be dynamic and changing, it is the interlocking nature of the many elements that makes them resistant to shifting direction. Moreover, there are significant incentives for incumbent market and other players to maintain the status quo of the overall innovation and development trajectory.

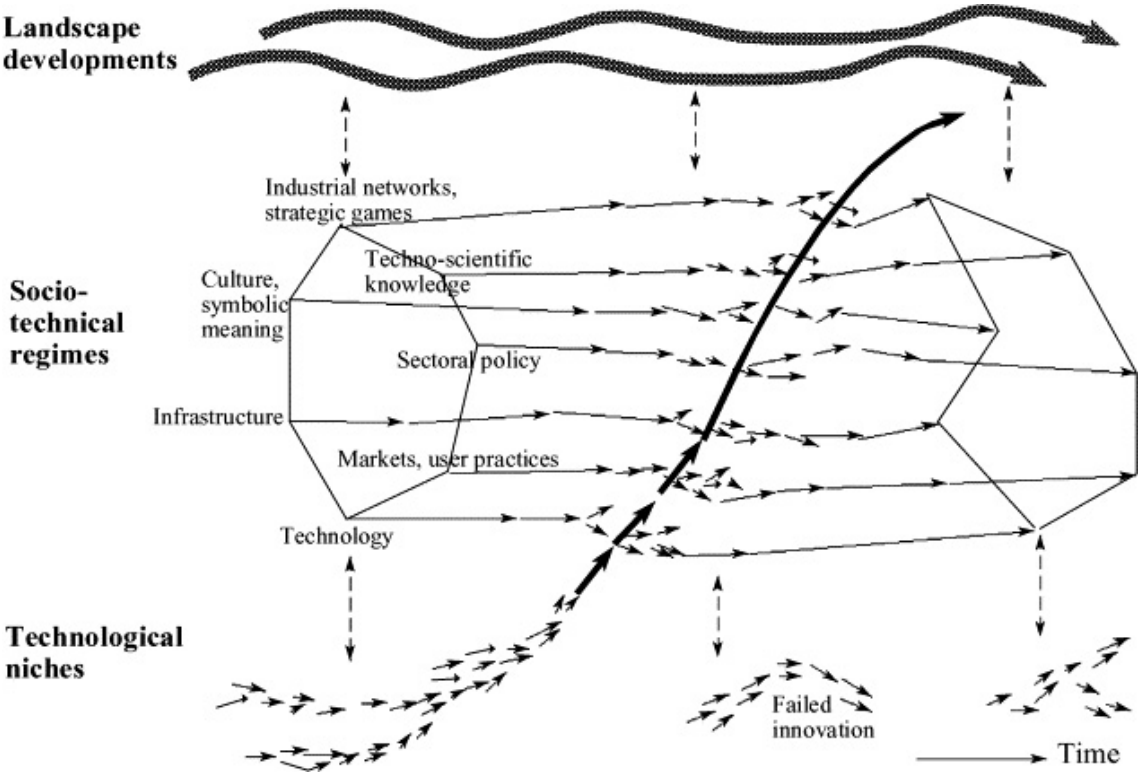
This in turn raises a number of questions about how transition and transformation take place. Clearly these are not purely technological phenomena. Transformation raises a question about the extent to which different domains of society (energy, transport, food and agriculture) and the structures and institutions of socio-technological regimes are capable of adapting so that a new "matching" of technology and structures and institutions can be achieved (Dolata, 2009). This issue could also be viewed as a question of the extent to which the societal, economic and policy conditions exist to allow technology and other innovation activity to exert disruptive pressure on existing structures and institutions, allowing a transition to a new socio-technical regime. Yet another way to explore how to bring about transition and transformation is to view it as a political question: What coalitions of interest are needed to reconfigure the regime and to create conditions for new societal objectives?

There have been a number of hypotheses about how the transition to new socio-technical regimes takes place. Arguably, the most prominent perspective and one that shares and elaborates many of the other perspectives discussed above is Geels's (2002) MLP. Geels envisages change processes taking place in different phases at different levels in a system: technological niches, socio-technical regimes, and landscape developments.

Geels *et al.* (2016) explains the power of this multi-level perspective as follows:

> *Instead of single drivers or a privileging of techno-economic factors, the MLP's key point is that transitions come about through the alignment of processes within and between these three levels. In this framework, acceleration of socio-technical transitions involves three mutually reinforcing processes: increasing momentum of niche innovations; weakening of existing systems; and strengthening exogenous pressures, which when aligned can create windows of opportunity. The resulting socio-technical transitions go beyond the adoption of new technologies and include investment in new infrastructures, establishment of new markets, development of new social preferences, and adjustment of user practices.*

Figure 3. A dynamic MLP on technological transitions



Source: Geels, 2002.

3.2.3 Transition pathways

While it is easy to become lost in some of the nuances, nomenclature and differing points of emphasis in the transitions literature, it does provide some key insights into the nature of transition pathways and processes (for one example of a typology of transition pathways, see Geels and Schot, 2007). It is worth noting at this point that there remain many as yet untested hypotheses in the literature about the nature of transition pathways in different contexts. It is beyond the scope of this study to describe all these different perspectives. Suffice to say that this is an active area of research and there is still significant debate about the policy mixes required to support transition and transformation (Schot and Steinmueller, 2016; Kern and Markard, 2016).

In terms of the transition to new pathways, it is important to bear in mind that an emphasis on directionality and sustainable innovation also brings new problems of political economy. Efforts to bring about transformations towards sustainability are likely to be deeply political and contested because different actors will be affected in different ways and may stand to gain or lose because of change (Meadowcroft, 2011; van den Bergh *et al.*, 2011; Patterson *et al.*, 2017). In the same way, the choice of different pathways to different transformation outcomes cannot be considered an apolitical choice. Large-scale and deliberate transformations of society invoke questions of representation: To whose agenda are we transforming (Stirling, 2008; Darnhofer, 2015)? As a consequence, a normative approach to transformation is unlikely to succeed because it leaves unquestioned the power dynamics in any particular context and thus likely exerts inertia on the pursuit of alternative pathways to sustainable and inclusive economic growth (Gillard *et al.*, 2016).

Mersmann *et al.* (2014) suggest that transition processes can be thought of as comprising of four different phases: pre-development, take-off, acceleration and stabilisation at a new level or relapse (see descriptions below and in Figure 4). It is easy to critique this as an oversimplification (and slightly linear view) of transition, and obviously the distinctions between phases are somewhat artificial and subjective. It is nevertheless a useful way to capture some of the key generic features of transition pathways. The key features of the four phases are illustrated below through two case study examples of transition processes in non-agriculture sectors

3.3 CASE STUDIES FROM NON-AGRICULTURE SECTORS

3.3.1 The transition to wind power electricity generation in Denmark

During the 20th century, Denmark, like most countries around the world, developed an electricity production and supply grid fuelled by fossil fuel technology. In the late 20th and early 21st century, it has emerged as a global leader in wind-powered electricity generation and has shifted from a central, utility-owned distribution network to a decentralised, privately owned distribution network. The development and use of wind turbines for much of the 20th century was driven by enthusiast – and artisan – produced-machines. Over time, coalitions of enthusiasts drew attention to the possibility of wind power production and ultimately set up wind power cooperatives. The shift to wind power as mainstream electricity generation has a number of local and global ingredients: (i) technological development in turbine design; (ii) the development of mass production techniques for turbines; (iii) a growing market for Danish turbines in California due to the global energy crisis of the 1970s that also increased interest in Denmark; (iv) the establishment of the European Wind Power Association; and (v) a growing interest in renewable energy that underpinned a policy environment in Denmark that supported both R&D and regulation (case study based on Pedersen, 2015).

3.3.2 The fall and rise of battery-powered electric vehicles

Although electric cars took an early lead in personal transport in the late 19th century, the 20th century quickly came to be dominated by petrol-powered vehicles and an associated regime of infrastructure, manufacturing and R&D capability, societal expectations and a wider fossil-fuel energy landscape. Starting in the 1960s and gaining momentum in the 1990s, growing societal concerns emerged over air pollution in major metropolitan areas and over climate change and environmental issues more generally. This social awareness created the conditions for the emergence of a growing number of electric car enthusiasts and niche manufacturers. It also stimulated regulatory pressure (most notably California's 1990 zero-emissions targets) and helped spur technological innovation. Despite resistance and policy U-turns in the early years, most mass car manufacturers now produce electric cars. While infrastructure and legislation have yet to catch up with political messaging about targets for the end of fossil-fuel cars in a number of countries, the shift to electric vehicles is now about "when" and no longer about "if". However, uncomfortable questions remain about the energy sources used to produce electricity for these zero-emissions vehicles, which largely remain fossill-fuel dependant in countries where the transition to renewable energy still has a considerable way to go (case study based on PBS, 2009; Wikipedia, 2019; Dijk *et al*., 2013).

3.3.3 The pre-development phase

Within this phase, development occurs along established pathways. Existing paradigms are (almost) unquestioned and institutions are stable. Some irritations exist, caused for example by external pressure or by symptoms of unsustainable development, which become more and more visible. Major stakeholders and key players, however, either are not aware of existing alternative solutions or perceive them as being too complicated, too costly, or otherwise unfeasible. This also the phase of pioneering activity and experimentation, often by peripheral players.

Illustrations from the case studies. In both the case studies, fossil fuel-based energy production and transportation regimes quickly became established in the early 20th century. Technology development, infrastructure and policy regimes advanced these regimes and, in many ways the motor car and cheap domestic electricity came to define the aspirations and achievements of society. Fuel shortages in Denmark during World War II encouraged the adoption of wind power. After the war, the Association of Danish Electric Utilities decided that it was not profitable to continue producing electricity from wind turbines. In 1957, a Danish wind power enthusiast constructed the Gedser wind turbine, at the time both a major breakthrough in the development of wind turbines and the biggest in the world.

3.3.4 The take-off phase

In this phase, the system starts to absorb new ideas and concepts. Irritation and problem awareness increase, and a number of different solutions to the problem at hand exist. In this phase, there is no common agreement on which (set of) solutions are the best. Technologies are not yet competitive, and business models are not yet firmly established. However, pilots and experiments continue to multiply. As alternatives spread more widely and become more visible, they become accepted as potentially realistic. On the other hand, proponents of the old system may switch from ignorance and mockery to concerted opposition as a possible paradigm shift becomes visible. Coalition building.

Illustrations from the case studies. The pathways of both cases were profoundly affected by the emergence of a greater environmental consciousness in the 1960s (albeit peripheral to the mainstream) and the energy crisis of the early 1970s. This situation slowly started to build policy support that mirrored changing societal values and in the case of the electric cars reflected growing concerns about air pollution. The work of pioneers became more prominent. Victor Wouk, the "Grandfather of the hybrid," built the first full-powered, full-size hybrid vehicle out of a 1972 Buick Skylark for the U.S. Federal Clean Car Incentive Program. The design and construction of the Danish Tvind wind turbine in 1975 by groups of volunteers, although widely mocked at first, were critical in raising awareness about the possibility of using wind power for electricity generation and were an important catalyst in building new support and advocacy coalitions around wind power. This support stimulated significant public investment in wind turbine research. In the early 1990s, following a tradition of being in the vanguard of emission legislation, the U.S. state of California led a regulatory push approach to the introduction of zero-emissions vehicles. During the late 1990s, many mass car manufacturers had advanced all-electric production programs, but by the early 2000s these were discontinued. In 2002, General Motors (GM) and DaimlerChrysler sued the California Air Resources Board (CARB) to repeal the zero-emissions vehicle law. The Bush Administration supported this opposition. In 2004 GM recalled all of its electric vehicles and had them destroyed.

3.3.5 The acceleration phase

In the acceleration phase, new solutions challenge the existing mainstream. They become acknowledged and widespread. The speed of change increases, and incidents in this phase may be broadly perceived as tipping points. The consequences for the larger system become apparent. The interconnections between different problems and sectors become more and more evident, and international cooperation may become more important. If the transformation runs successfully, technological, institutional, social and economic innovations mutually reinforce each other. (The more people buy eco products, for example, the cheaper they and the more shops sell them – which makes more people buy eco products. The more people are interested in car sharing, the more it becomes a business model, the more companies enter the market, and the more cars become available, making it more attractive for new customers.) Opposition to the transformation, however, may continue or even increase radically by the former "winners" of the previous development pathway, who may now face severe losses in political or economic terms.

Illustrations from the case studies. The electric vehicle case study is currently in the acceleration phase, helped, in part, by a range of significant public investments in technology development, by subsidies to producers and consumers and by regulation. Consumer attitudes towards electric vehicles have also changed, owing, partially to technological and design advances and partially to changing values and interest in environmental issues. There have been spillover effects of more general, larger changes in ambition toward low carbon growth, sustainable cities and sustainable development. Vehicle numbers have increased rapidly from a relatively low base in 2010. By 2014, there were over 500,000 plug-in electric passenger cars and utility vans in the world, and 1 million by 2015. Norway achieved the milestone of 100,000 all-electric vehicles registered in December 2016, the first country where 5% of all registered passenger cars were a plug-in electric cars. India announced in 2017 that it would go 100% electric by 2030 but quickly scaled this back to 30% by 2030. This reflects the ongoing infrastructural, technological and political hurdles that remain in the transition to electric vehicles.

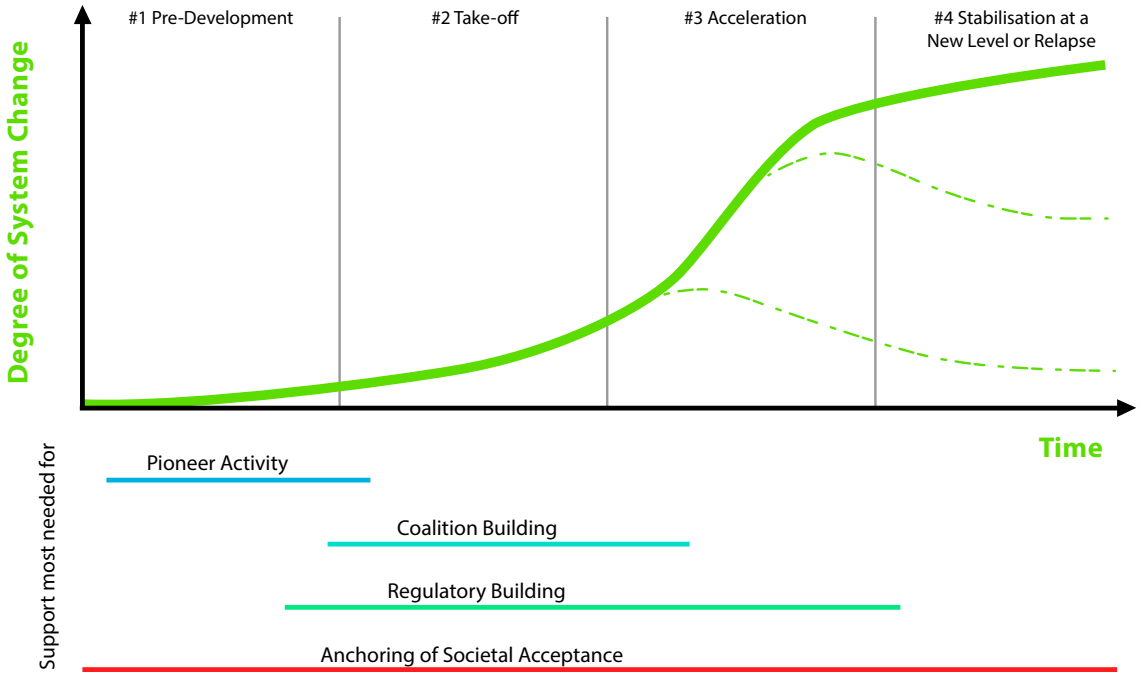
During the acceleration phase of Danish wind power, a parliamentary decision was taken in 1996 that 10% of the electricity demand should be met by wind power by 2005. This goal that was achieved well ahead of time, in 1999. Reasons for this include the unique cooperative wind turbine sector; strong political encouragement for renewable energy production; membership in European associations and the development of a cross-border energy market; strong capability in research and design, including international collaboration; and world-leading capability in turbine manufacturing and export. These aspects – nurtured during the take-off phase by pioneers, producer and user networks, and significant public investments – were given added impetus by the political commitment to develop an energy regime that reflected Danish societal values and that were triggered in part by a society-wide rejection of nuclear energy.

3.3.6 Stabilisation or relapse

The magnitude of change decreases, and the system stabilises. Stabilisation may occur at any level, from a total relapse to the system's original state if structures and proponents of the "old"system have proved more persistent, to a fully transformed system if the process has proven effective. The change will be transformational if old barriers have been overcome and new barriers hinder the reversal of the transformed system.

Illustrations from the case studies. While the electric vehicle case, even in pioneer countries, has yet to reach the stabilisation phase, the Danish wind power case has. By 2003, the Danish wind turbine industry was the world's largest, and Danish companies accounted for 38% of the world turbine market. Currently, about 40% of electricity is generated by wind power and contributes to significant energy exports through the Nord Pool regional power market. To encourage investment in wind power, families were offered a tax exemption for generating their own electricity within their own or an adjoining commune. This could have involved purchasing a turbine outright, but more often families purchased shares in wind turbine cooperatives, which in turn invested in community wind turbines. By 2004, over 150,000 Danes either where members of cooperatives or owned turbines, covering about 5,500 turbines or 75% of turbine ownership. This pattern of ownership was critical in developing deep societal acceptance and thus political support for wind power. In recent years, the sector has seen some adjustments: a shift toward private rather than cooperative owner ship of turbines, a shift to fewer but larger turbines, and a shift to offshore wind farms. Political commitment to renewable energy remains strong, but energy plans to 2050 embrace a range of renewable energy sources, not just wind power. These include solar, geothermal, wave and any others that may become interesting in the next 35 years. This is thus part of an ongoing change in the overall energy landscape.

Figure 4. Phase model of transformation processes



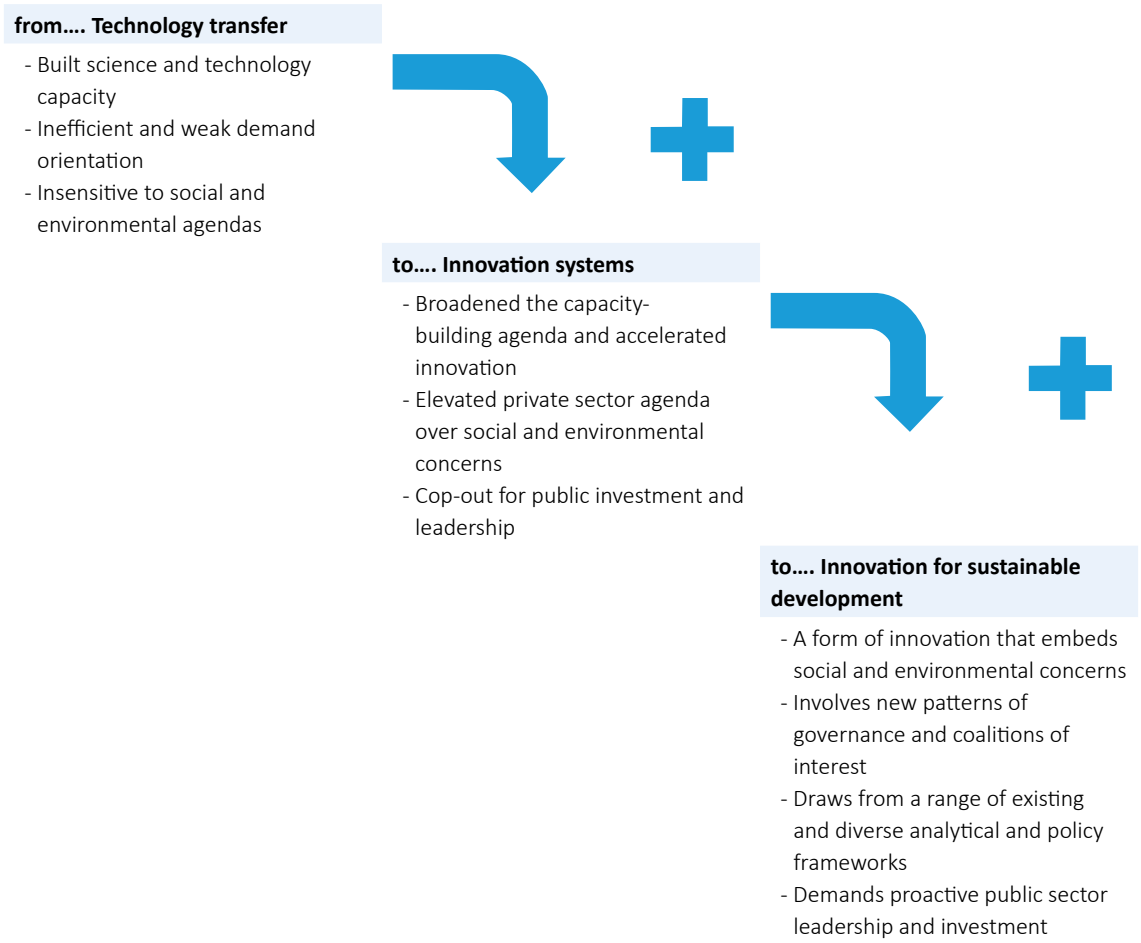
Source: Mersmann *et al.*, 2014.

3.4 IN SUMMARY

This chapter has reviewed recent thinking about the way the sustainable development agenda has reframed innovation and suggests that system innovation needs to become a much more prominent perspective. This in turn raises issues about the socio-political nature of transformational change processes and the need to consider technological change as part of this sort of multi-phase and multi-scale process.

By way of a summary, Figure 5 borrows from Schot and Steinmueller's (2016) notion of Innovation 3.0 to illustrate the evolving and broadening of the framing demanded by the sustainable development agenda. For the agri-food sector and indeed for other sectors too, the precise contours of this new paradigm of innovation for sustainable development are yet to be defined. The remainder of this study illustrates how innovation has played out in past agri-food system innovation, how it is likely to play out in the transition to sustainability, and what the implications of this might be for public agricultural research organisations.

Figure 5. Evolving framing of innovation for sustainable development



4 TRANSFORMATION IN THE AGRI-FOOD SECTOR: CASE STUDIES

4.1 INTRODUCTION

This chapter explores transition and transformation processes in the agri-food sector. The previous chapter introduced frameworks that explain the nature of the transition processes that leads to the emergence of new socio-technical regimes that both enable and enact innovation aligned to sustainable development ambitions. Notable in this discussion is the multi-phase, multi-level understanding of transition and transformation. Much of this conceptualisation has emerged from analysis and observation of energy transitions and clean production transitions in OECD countries. The purpose of this chapter is to illustrate and understand the nature of transformation in the agri-food sector and explore whether or not the processes of innovation and change observed are similar to those discussed in the previous chapter.

The chapter relies on a set of 16 case studies (the approach and selection of case studies is discussed in detail below in the case study methods section). While the case studies were written as purely historical accounts without any analytical framing, the analysis in this chapter adapts some of the framing of *system innovation* highlighted in the previous chapter to illustrate and explore agri-food sector innovation and transformation. Having presented a discussion of the case studies, the chapter then compares and contrasts the agri-food sector transformation processes observed with experiences from other sectors.

4.2 CASE STUDY METHODS

The case studies, presented in full in the accompanying *Resource Document I: Case Studies*, are historical accounts of innovation processes and pathways. They are based on secondary information (journal articles, grey literature, published evaluations). The emphasis in the case studies presented in the resource document is the description of events and the presentation of evidence rather than interpretation through any particular conceptual perspective. The preparation of each case study was guided by an outline with the following sections: introduction, challenge or opportunity being tackled, description of the innovation, innovation pathway, impact evidence and consequences (see Annex 1).

The logic of case study selection requires some explanation as this was shaped by the wider process that this study emerged from and has led to some acknowledged shortcomings in a few of the selected cases. The collection of case studies was developed as a part of

two ISPC and CSIRO projects and a longer-term collaboration investigating emerging modes of agri-food system innovation. These projects sought to develop a database of emerging innovation practice that was having impact at scale and also aimed to support a multi-stakeholder process to discuss the implications for public agricultural research (Hall *et al.*, 2016; CSIRO and CGIAR ISPC Secretariat, 2016, 2017). In the first phase of this work, stakeholders were asked to suggest case studies that could illustrate innovation processes that led to impact at scale. An initial analysis of the cases selected in the first round quickly highlighted that although rare, impact at scale was associated with a form of innovation involving systemic change and system innovation and that the processes observed seemed to fulfil accepted definitions of the term "transform" (Hall *et al.*, 2016; CSIRO and CGIAR ISPC Secretariat, 2016, 2017)

Building on this first phase of work, the next project explicitly focused on better understanding the nature of innovation in cases of agri-food system transformation. In the second round of case study selection, suggestions for case studies were again made during the stakeholder workshops (CSIRO and CGIAR ISPC Secretariat, 2016, 2017). The suggestions received were filtered using the following criteria:

- Cases were recognised by different stakeholder groups (funders, researchers, etc.) as examples of profound changes taking place that appeared to be “transformational”;
- Cases included a mix of domestic (Australian) and international cases;
- Sufficient secondary documentation was available of the historical evolution of the case, including evaluations and evidence of impact; and
- Cases were not projects but major change processes in the agri-food sector with sustained impact not dependent on external interventions.

The case studies from both phases of the project were developed into the format outlined in Annex 1. This produced 16 case studies, summaries of which are presented in Table 1.

In retrospect, although some of the cases present some aspects of transformation, it is obvious that not all 16 cases are transformational in the strict sense of the definitions found in the current literature discussed in Chapter 3. In part, this reflects the stakeholder process through which cases were identified, where the term "transformation" was used rather loosely.

The second issue in case study selection was that while there is considerable discussion in the literature of exciting new transformations with relevance to sustainable development in the agri-food sector, these have yet to mature sufficiently to illustrate how the transformation process plays out (and this may take decades). As a result, there is little literature beyond description of the concepts. Examples include smart cities, the bioeconomy, and industry 4.0.

This study addresses these case study shortcomings in three ways. First, the bulk of the analysis in this chapter concentrates on a subset of seven case studies that in retrospect better fulfil the transformation criteria of demonstrating system innovation and directionality of innovation towards sustainable development objectives (the case study short listing process is described in brief in the next section). Second, some additional non-agri-food case studies dealing with contemporary sustainable development issues were presented in the previous chapter to illustrate current transition concepts. These case studies – electric vehicles and wind power – are used to help compare, contrast and amplify, where necessary, the experiences of the agri-food sector documented in the 16 case studies. Third, in Chapter 5, which addresses the implications of transformation for public agricultural research organisations, emerging transformations, illustrated by the example of the bio-economy, are used to elaborate a more forward-looking scenario on the role of public agricultural research organisations.

Table 1. Case study summary table

CASE	CHALLENGE / OPPORTUNITY	INNOVATION	IMPACT INDICATION	CONSEQUENCES
Australian cotton 1 + 2	Competitiveness in global marketplace; social and environmental licence to operate	Deployment of transgenic varieties and water efficiency measures with concomitant institutional changes	Sector-wide impact with significant economic and sustainability returns	Broad network of industry players to adapt and deal with future challenges and opportunities
BARLEYmax™	Biofortification of agricultural products using selective breeding to address micronutrient deficiency	Development of biofortified barley combined with bespoke agronomic and post-harvest practice; venture capital to support continuing R&D and value-chain expansion	Potential health and nutritional benefits estimated, to date, to amount to about A$300 million	Technology and lessons from BARLEYmax™ applied for nutritional benefits in other grains; international market expansion for new food products
EADD hubs	Development of effective input and output markets, services, and value chains for smallholder dairy farmers	Networks of input and service providers clustered around dairy collection hubs	"Mature" smallholder dairy areas continue to thrive, but limited evidence of smallholder dairy-led rural transformation	Agglomeration of services in dairy hubs that extend well beyond those strictly related to farming (banking, insurance and health); evolution to bespoke, non-chilling plants hub models
ECF ITM	Use of technological breakthroughs from the 1950s and 1960s to control economic losses from ECF in eastern and southern Africa	Partnership arrangements to reignite delivery of stalled ECF-control product and services	Potential for subsector-wide impact; over 1.5 million doses administered in eastern and southern Africa	Subsector-wide capacity-building; system innovation deployed to deliver other products and services
FMD Philippines	The planning, the resourcing, and the eradication of FMD in the Philippines	Ex ante cost-benefit analysis stimulates private sector co-investment in control measures and government rules and regulatory changes	Sector-wide impact with significant economic and social returns	Purpose-built FMD alliances and networks retooled to respond to other sector challenges and opportunities
Forage, Indonesia	Disseminate results of livestock feed practices research to contribute to self-sufficiency in cattle production	Promotion of technology through extension methods and farmer organisation development	Limited to project domain	Network of livestock researchers continues to foster incremental change in project area

CASE	CHALLENGE / OPPORTUNITY	INNOVATION	IMPACT INDICATION	CONSEQUENCES
Golden Rice	Address VAD in the rice-consuming populations of Asia	Change Asian diets through a combination of biotech beta-carotene-fortified rice, IP arrangements for commercial and public use, and a global consortium of international public research, private seed companies, and philanthropic foundations	No producers or consumers have yet adopted Golden Rice	Possible biotech solution to VAD caught in science policy controversy as part of the debate for and against GM crops
Marine Stewardship Council	Unsustainable fishing and the safeguarding of seafood supplies for the future	Market-led, voluntary, independent assessment and certification system for well-managed and sustainable fisheries with labelling of certified products at point-of-sale and traceability for product supply chains	Twelve % of wild-caught seafood is MSC certified with market value of US$5 billion per year (in 2016)	Certification and labelling programme, supported by science and technology advances and commercial interests, advancing system innovation across the wild-caught fishery sector; has fomented a similar initiative for aquaculture
Mass marketing treadle pumps	Mechanisms to improve access to irrigation by poor farmers	Design and nurturing of a low-cost foot pedal pump and its bespoke value chain	About 1.3 million treadle pumps installed; investments have generated an estimated net return of US$150 million per year	Disrupted existing water markets enabling the poor to participate in these
Novacq™	Substitutes for fishmeal and fish oils in prawn feeds that are able to compete in the market with prawns grown on feed that is based on fish products – without current environmental and price implications	Applied research develops non-marine sources of protein for fish feeds, tested and commercialized through national and international research and private sector partnerships	Local-scale economic and environmental impacts already documented	Inclusion of feed technology in species beyond crustaceans likely to further revolutionize aquaculture feed industry, while reducing cost and environmental impact
Orange-fleshed sweet potato	Biofortified OFSP as a complementary approach to reducing VAD in sub-Saharan Africa	Dissemination of research product through significant investment by philanthropic foundations in solving system and market failures at local levels, and nutrition education at the community level	Thus far, largely limited to project domain	Significant improvement in the vitamin A status of the individuals who participated in the project-level interventions

CASE	CHALLENGE / OPPORTUNITY	INNOVATION	IMPACT INDICATION	CONSEQUENCES
Water use efficiency, Queensland	Deliver sustainability with profitability in response to new public policy and market regimes	Monetary incentives coupled with the adoption of new and existing WUE solutions, anchored around a simple monitoring management system with shared targets agreed by a multi-stakeholder partnership	Sector-wide impact with significant economic and sustainability returns (in Queensland)	Improvements in availability of appropriate and effective technologies for WUE; development of sector-wide networks and delivery mechanisms
Salmon production, Chile	Generate industries that leverage the nation's natural resource endowments	Three phases: building capacity to produce; commercial expansion; and globalization and adaptive responses to crisis and new regulations	Nationwide impact with significant economic returns	Lessons from the salmon industry are likely to prove relevant in future attempts to develop or expand other industries in a socially equitable and sustainable way
Seeds of Life, Timor-Leste	Contribute to post-conflict food security	Development of crop varieties combined with changes in seed production and dissemination as well as policy	Major impact on staple food production: projected to increase by 30% to 2026	Critical need for ongoing expenditure to support (i) continued variety importation and testing; (ii) seed multiplication; and (iii) seed purchase and distribution
Sundrop Farms	Turn technology for environmentally sustainable, intensive horticulture into a profitable business	Integration of established technologies and mix of public and private funding to create a large-scale agricultural value chain that does not rely on traditional inputs	Estimated 5 to 15% cost saving over fossil fuel-powered glasshouses	Strategic partnership arrangements provide an example for pioneering new approaches in agri-food systems
Thai poultry exports	Recover poultry export market position lost by HPAI outbreak	Rapid change from export of 65% raw/frozen and 35% cooked poultry products to close to 100% cooked products for duration of the export ban	Export broiler industry recovers from HPAI-related export ban to regain fourth position in the world for total chicken exports by value and as the largest exporter of prepared chicken within three years	Reduced vulnerability to loss of export markets in the event of another disease outbreak; further consolidation of Thai poultry export industry

4.3 TRANSFORMATION IN ACTION IN THE AGRI-FOOD SECTOR

This section uses a subset of case studies to illustrate and elaborate the nature of transitions and transformation in the agri-food sector. It does this using an analytical framing based on concepts from the previous chapter that outlined a contemporary understanding of transitions and transformation for sustainability as a form of innovation that has the following characteristic features:

- *System innovation*. Changes in both the production and consumption system as well changes in the component parts including spread and use of individual technologies. Also referred to as the emergence of a new socio-technical regime.

- *Directionality*. Purposeful actions, policies and investments specifically designed to shift the direction of the innovation trajectory and the development pathway towards inclusion and environmental sustainability as well as economic growth.

- *Multi-scale multi-level*. Change process that involves a nested hierarchy of technological change and innovation across scales of local/individual use and practice, socio-technical regime or paradigm, and landscape or societal level, where it is the interactions across these scales that can either create path dependencies or stimulate adaption and transformation of systems. This nested hierarchy reveals the interconnection of sustainability issues at higher scales.

- *Phasing*. Change process that takes place over extended period involving pre-development, take-off, acceleration and stabilisation phases. Experimentation by niche peripheral players gains sufficient societal and political acceptance to stimulate wider regime changes. Frequently this occurs when sustainability challenges become sufficiently serious to prompt action or when changing societal values make old practices unacceptable. Emerging coalitions of interest create political imperatives to stimulate public research and innovation investment and regulation. This is often initially challenged by incumbents but is subsequently embraced as the new mainstream.

As discussed earlier, this chapter focuses on a subset of cases that best exemplified the different dimensions of transition and transformation processes. Table 2 analyses the attributes of all 16 case studies through the lens of the four characteristic features described above. This analysis was subsequently used to select the subset of seven case studies that follow.

Table 2. Transitions and transformation for sustainability: Case study characteristics

CASE	SYSTEM INNOVATION	DIRECTIONALITY	MULTI-SCALE/ MULTI-LEVEL	PHASING
Australian cotton 1 + 2	**	**	**	Stabilisation
BARLEYmax™	*	*	-	Take-off; potentially part of a wider transition to sustainable agri-food systems
EADD hubs	*	-	-	*Not applicable*
ECF ITM	*	-	-	*Not applicable*
FMD Philippines	**	*	*	Take-off; potentially part of a wider transition to sustainable agri-food systems
Forage, Indonesia	-	-	-	*Not applicable*

CASE	SYSTEM INNOVATION	DIRECTIONALITY	MULTI-SCALE/ MULTI-LEVEL	PHASING
Golden Rice	*	-	-	Pre-development; potentially part of a wider transition to sustainable agri-food systems
Marine Stewardship Council	***	**	**	Acceleration; part of a wider transition to sustainable agri-food systems
Mass marketing treadle pumps	**	**	**	Acceleration, but eclipsed by other change processes
Novacq™	*	*	-	Take-off; potentially part of a wider transition to sustainable agri-food systems
Orange-fleshed sweet potato	*	*	*	Take-off; potentially part of a wider transition to sustainable agri-food systems
Water use efficiency, Queensland	**	**	***	Stabilisation
Salmon production, Chile	***	***	***	Stabilisation
Seeds of Life, Timor-Leste	-	-	-	*Not applicable*
Sundrop Farms	*	**	*	Take-off; potentially part of a wider transition to sustainable agri-food systems
Thai poultry exports	**	**	**	Stabilisation

4.4 MARINE STEWARDSHIP COUNCIL (MSC): IMPROVING THE SUSTAINABILITY OF CAPTURE FISHERIES THROUGH SUSTAINABILITY CERTIFICATION

This case study illustrates the way, against a global backdrop of increasing environmental awareness, an advocacy player has been able to catalyse an important sustainability transition that is dramatically changing fishing practices globally.

An international NGO and a multinational company, supported by science and technology advances, provided the initial leadership that led to the formation of MSC in 1997. MSC aims to safeguard wild-caught seafood supplies for the future through an assessment and certification process of seafood products against a sustainable fisheries standard. Although the two organisations had different motivations – conservation and commerce – they shared the same objective of ensuring the long-term viability of global fish populations and the health of the marine ecosystem. Following the certification of the first fishery in 2000, the MSC "blue tick" logo can be seen on fish counters and in restaurants throughout the world. It is estimated that in 2017, 12% of wild-caught fish, with a market value of US$5 billion, were MSC certified. Independent studies show that MSC certification of fisheries contributes to the recovery of fish stocks.

The key system innovation has been the adoption of new fisheries standards by industry players, governments and civil society groups, and this in turn has ushered in technological change in the industry to comply with environmental standards. At the same time, consumer awareness about the

negative environmental aspects of fishing has been increasing. The formalization or institutionalization of new values in the form of certification and labelling gave consumers the choice to buy sustainably sourced fish, which helped increase demand for sustainable produce and provided commercial incentives for retailers and suppliers to support the new sustainability-promoting actions. A nested hierarchy of change processes is also evident, with fishing practices, consumer preferences, industry regulation and global environmental concerns working together to support the shift to sustainable fishing practices and enabling innovation to support this.

In terms of phasing, a number of environmental advocacy groups have been lobbying for change in the global fishing industry since the 1960s, a pre-development phase that lasted into the 1990s. It was only in the late 1990s, however, that sustainability concerns that threatened their commercial viability (coupled with consumer awareness) reached a level where industry players shifted from opposing regulation, to embracing it. The transition to sustainable fisheries globally is still underway and is currently in an acceleration phase. Certification is only part of this process. Recent concerns about plastic pollution of marine ecosystems highlight that sustainable fishing practices are only part of a larger scale set of sustainability issues that affect marine ecosystems.

(Source: Dijkman, 2019a)

4.5 THE TRANSITION OF THE CHILEAN SALMON INDUSTRY TO SUSTAINABLE AND SOCIALLY INCLUSIVE PRACTICES

The history of the Chilean salmon industry illustrates both transformation in the sense of the establishment a new and economically successful subsector, as well as a subsequent sustainability transition. Public investment in the development of commercial salmon farming in Chile was part of a government policy in the 1970s of promoting scientific and technological innovation that added value to or generated industries based on the country's natural resource endowment. The rapid expansion and economic success of the industry, however, outpaced the development of socio-political institutions required for environmentally friendly and sustainable natural resource exploitation, social inclusiveness and equitable outcomes for local communities. Pressure from civil society organisations on industries globally raised the importance and consideration of labour standards and environmental protection in food supply chains. Today, Chile remains the second-largest salmon exporter globally, with an annual export value of over US$4 billion, and the salmon industry directly provides 30,000 jobs.

This case illustrates the way in which a response to a local environmental and social crisis within the industry can shift the direction of practice and innovation towards ethical and sustainability objectives. There was, however, a wider global context, with pressure from civil society organisations on industries worldwide to tackle labour standards and environmental protection in food supply chains. To maintain social licence (and market share), countries like Chile had to respond not only through technological innovation, but also with organisational and business innovation and regulation. The transformation process in the Chilean industry was therefore multi-level multi scale, involving changes in the way salmon are produced and the way the sector was regulated, and this reflected and embodied the new values and norms of the global market.

In terms of phasing, the predevelopment phase of the transition of the Chilean salmon sector began in the early 1990s with the environmental impacts of salmon farming being raised as early as 1991. By 1999, labour conditions on salmon farms and the displacement of fishing communities had entered the discussion. From 2002, conflicts between NGOs, unions and salmon farmers intensified. A government-orchestrated national dialogue in early 2002 led to the Salmon APL (Clean Production Agreement of Salmon) as a voluntary system

of environmental certification. Over time, under pressure from NGOs, the salmon industry began to engage actively in the APL. Despite some initial tension, this represented the take-off phase for the transition and sparked the emergence of powerful coalitions of national and international NGOs advocating for adoption of new environmental and social practice in the industry. The outbreak of infectious salmon anaemia in the late 2000s (partly, a result of poor environmental management in fish production) cemented and accelerated the transition process because of its economic consequences. This also led to further regulation and stimulated innovation in production practices.

(Source: Hays *et al.*, 2019)

4.6 SUNDROP FARMS: SUSTAINABILITY PIONEERS IN THE AUSTRALIAN FOOD SYSTEM

The case of Sundrop Farms is a useful illustration of the way sustainability pioneers are starting to establish new business models that demonstrate sustainable production systems and link them with the mainstream food retailing industry. While this is not an example of total system innovation at the scale of the agri-food sector, it is nevertheless evidence that in countries like Australia, the transition to a more sustainable food system is both possible and starting to happen, albeit slowly.

In 2012, Sundrop Farms, a UK-based agri-business with operations in Australia, Portugal and the United States, developed and patented a system of greenhouse crop production that does not depend on fossil fuels, arable land and fresh water resources. Having successfully tested the technology in a pilot facility in Australia, Sundrop Farms worked with a number of commercial partners to expand the Australian facilities and bring the first consumer product to market. The company estimates total annual cost savings at between 5 and 15% compared with fossil-fuel-powered glasshouses. Reductions in carbon dioxide emissions, fresh water and diesel fuel use are estimated to amount to 26,000 tonnes, 450 million litres, and 2 million litres, respectively. The Sundrop Farms System™ integrates established technologies from across the world (solar thermal systems, greenhouse design, hydroponic systems, vertical farming, desalination technology, etc.) in a novel form. The company received considerable venture capital support and government investment in Australia. It notably signed a 10-year contract with one of Australia's major supermarket chains to supply all of its tomatoes.

The role a sustainability pioneer like Sundrop plays in the transition is that it helps demonstrate a sustainable alternative and provides evidence that such an alternative can benefit different value chain actors, including consumers. This is typical of the sorts of activity that emerge in the early take-off phase of transition and that help create societal and political awareness of new directions. While this example is private sector-led, it received significant public support. A key issue in this case was that the point in the transition process had been reached where a supermarket chain saw value in providing its consumers with produce with sustainability credentials. This suggests that societal-level changes in values were already under way, although this maybe not yet have translated into legislative support.

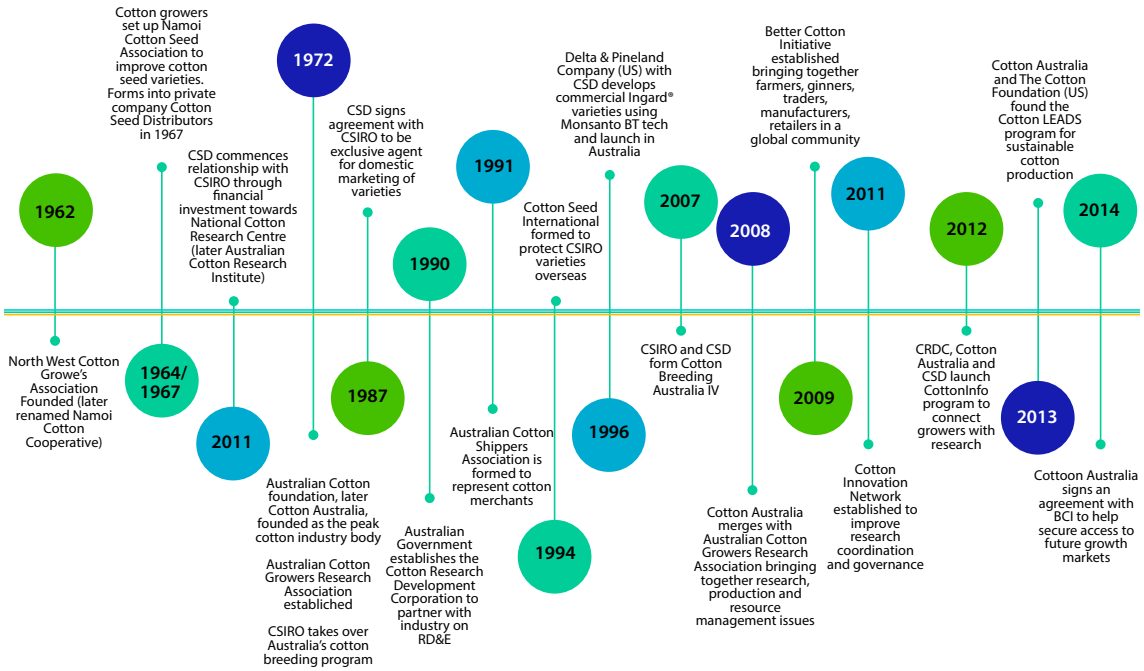
(Source: Hays and Hall, 2019a)

4.7 AUSTRALIAN COTTON: INDUSTRY-LED NATIONAL AND GLOBAL INNOVATION ALLIANCES FOR SUSTAINABILITY

The cotton case in Australia illustrates that when sustainability issues reached the point of threatening the cotton industry as a whole, a sharp shift towards sustainability took place through the introduction of a series of sustainably innovations. Critical to this shift was a unique and evolving organisational landscape and patterns of alliances (Figure 6).

Australian-bred cotton varieties dominate cotton production globally, producing the highest yields. Australian cotton is the most sustainably farmed globally. The history of the Australian cotton industry owes its origins and early genesis to high levels of public investment in water infrastructure and subsidies to incentivize farmers to grow cotton. Starting in 1974, collaboration between industry and the private sector supported research and development of new cotton varieties and other production technologies. In the late 1980s and 1990s, as a response to threats to its social licence as a result of pesticide contamination and land and water degradation, the industry introduced environmental best management practices. This was based on a novel type of co-regulation between government and farmer industry bodies. Important technological breakthroughs also supported the transition to sustainable practices and the system innovation that accompanied it. Notably, the development of transgenic Bt cotton varieties with built-in tolerance to the *Helicoverpa* caterpillar was a key tool in farmers' pest management strategies.

Figure 6. The institutional development of the Australian cotton sector



The industry was uniquely positioned to innovate towards sustainability because of the nature of the relationships between industry organisations and public research, but also because of how the industry was able to broker partnerships to implement new production practice standards, notably the industry's best management practices (BMP). Part of the power of this architecture of partnerships was that when sustainability issues reached a critical point, the solutions were self-regulatory (rather than imposed) but at the same time did not lose sight of the need to maintain the profitability and competitiveness of the industry. Industry organisations also evolved significantly over this time (from the mid-2000s onwards) reflecting the changing needs of the sector (particularly the changing demands of cotton consumers), and this in turn helped drive research priorities (see Figure 6 for time line). Recent years have seen the Australian cotton industry organisations joining international networks, such as the Good Cotton Initiative, that recognise the global market importance of ethically and sustainability produced cotton and act as an alliance to promote these practices. Best management practices certification in Australia has been key to accessing new international markets.

In terms of phasing, it could be argued that the Australian cotton sector is in the stabilisation phase of transition. Policy and institutional arrangements and patterns of innovation activity are aligned to sustainability objectives, and production practices and capabilities support this. The challenge on the horizon, however, is climate change and the questions it raises about the sector's ability to maintain sustainable practices in an increasingly water-constrained environment. Similar to the other cases discussed here, transition achievements are nested in bigger landscape – level change processes – in this case, a transition to an agricultural production regime better suited to a climate-constrained environment.

(Source: Hays and Hall, 2019b; Taylor, 2019a)

4.8 WATER USE EFFICIENCY (WUE), QUEENSLAND: NEW ALIGNMENTS OF STAKEHOLDER AGENDAS UNDER CRISIS CONDITIONS

This case study demonstrates among other things, the critical role of socio-political dynamics in the transition to sustainability. In this case, a prolonged drought in the Australian state of Queensland helped forge an unlikely alliance of traditionally antagonistic stakeholders who then worked together in the early 2000s to implement and monitor new water use regulations. The approach increased agricultural productivity by a $280 million, equivalent to supplying an additional 180,000 megalitres (ML) of irrigation water per year, while annual water savings of approximately 20,000 ML were achieved.

From 1999 onwards, a purposeful policy intervention was put in place to create a partnership between industry and government to improve agricultural WUE across agricultural subsectors in Queensland. This was achieved by improving the use and management of existing irrigation water. The development of shared goals between government, industry, civil society and research partners and the co-development of a monitoring system were critical success ingredients. The resulting partnership also led to delivery programmes that served to organize and incentivize adaptive research and farmer responses and build industry capacity. The partnership architecture established has subsequently been used for other natural resources management challenges facing the agricultural sector such as run-off pollution.

(Source: Taylor, 2019b)

4.9 THAI POULTRY EXPORTS: SUBSECTOR TRANSFORMATION THROUGH INDUSTRY REINVENTION

This case study shows how a well-established and globally significant export industry was disrupted by animal health issues with longer-term consequences. Being denied access to all export markets, the Thai poultry industry could have totally collapsed. Instead it recreated itself into a new type of globally competitive player.

The 2004 outbreak of highly pathogenic avian Influenza (HPAI) brought an abrupt halt to more than three decades of impressive year-on-year growth in the Thai poultry industry. The industry was at that time the world's number-one exporter of value-added poultry and fourth overall producer of broiler meat. In response to the outbreak, all importing countries banned imports of raw poultry meat. At that time, 65% of poultry exports comprised raw, frozen meat and 35% were cooked products. In response to the outbreak, more stringent biosecurity, food hygiene and animal welfare regulations and standards were enforced by the Thai government and importing countries. The predominant business model shifted from contract rearing to fully vertically integrated farm-to-fork poultry businesses. In response to the ban on raw meat exports, the large integrated companies were also able to access finance and very expand their existing processing capacity. In 2003, just 39% of the value of exports were cooked products. Between 2004 and 2013, this proportion increased to over 90%. The shift to predominantly cooked poultry products means that, in the event

of another HPAI outbreak, Thailand will be able to continue exporting, avoiding a severe dip in exports as experienced in 2004.

While this case is not a sustainability transition in the strictest sense, it does illustrate the way new regulatory conditions (biosafety, animal welfare, etc.) can bring about major changes in the direction of the health and food safety performance of an industry. It was the large, well-resourced companies that were able to respond, and this resulted in the forcing out of many smaller-scale contract producers. If anything, this crisis and response consolidated the position of incumbent players, who remain in control of the rules of the game in this industry. This has allowed the system to stabilise at a new level, but the social and environmental performance of this new system remains unclear.

(Source: Dijkman, 2019b)

4.10 MASS MARKETING TREADLE PUMPS IN BANGLADESH: AN APPROPRIATE TECHNOLOGY PATHWAY TO TRANSFORMATION

The case study illustrates how technology can be leveraged to underpin inclusive development by creating systemic changes in a particular domain of activity that the poor were previously excluded from. In this case, the introduction of treadle pump technology appropriate to resource-poor rural households helped them gain access not only to irrigation was but also to water markets. These markets had previously been the domain of owners of capital-intensive diesel pumps only. The introduction of the tread pump led to the emergence of more inclusive water services, positioning the poor to take advantage of the subsequent introduction of cheap Chinese diesel pumps.

The history of the case begins in the early 1980s and a programme led by an NGO, International Development Enterprises (IDE), to facilitate smallholder access to irrigation in Bangladesh. The NGO took proven manual pump technology and sought to facilitate the development of markets for manufacturing, retail, installation and maintenance of the pumps that would persist independently of project support. At the household level, significant production and income benefits were recorded from the relatively small investment required to purchase a pump, providing autonomy to small farmers on irrigation timing and amount, without the additional cost of fuel. In the long term, the treadle pump can be seen as an intermediary step towards mechanical pumping, with increased income enabling purchase of cheap diesel pumps from China as they became available. The treadle pump is also said to have contributed to the restructuring and development of water markets in Bangladesh, challenging the established monopolies of large landholders in water access. The total donor investment of US$10 million is estimated to have leveraged an investment of US$40 million from smallholders and generated a net return of US$150 million a year.

The NGO involved was somewhat unusual in that it was pioneering the delivery of products and services to the poor via a market mechanism. Having demonstrated the value of this inclusive innovation, local informal sector engineers copied the pumps, reverse engineering the design to produce low-cost versions, which quickly became popular. This led to the establishment of an integrated system of suppliers and repairers in rural areas. The public sector contributed by agreeing to remove subsidies from other small-scale pumps in the market that were discouraging the private sector from producing and supplying pumps. While this case is often presented as a technology narrative (over a million pumps were sold), the real transformation process was the way in which poor households were enabled to participate in water markets. Technology certainly helped, but there was a degree of serendipity in that it was introduced at a time of wider agrarian change in Bangladesh.

(Source: Williams, 2019)

4.11 PATTERNS OBSERVED IN THE CASE STUDIES

The case studies presented above are of two distinctly different types. The first are historical accounts of transformation and transition processes unfolding over many years, usually in a particular subsector or industry such as Chilean salmon, Australian cotton and WUE. The second are “snapshot” examples of a particular set of activities that are often indicative of bigger transitions taking place in the background. The Sundrop Farms case, for example, is about one company trying to occupy a new market space that has opened up because of increasing interest and value at the landscape level in sustainability in the agri-food system in Australia.

The first group of case studies shows how, technology, regulation, coalitions of interest, private sector activity and market forces have been drivers at different points in the transition process. These cases do not suggest that any one of these drivers on its own is causing transition and transformation. Rather, they suggest that these drivers play an important role at specific points in time and are often a response to a changing context and set of values. For example, the MSC case could be seen as a certification-driven transition to sustainability in the global fishing industry. In reality, this was an idea whose time had come. Increasing environmental awareness and sustainability issues were starting to raise economic concerns with major sector players, which in turn created options for a coalition to work on addressing the problem. Consumers’ interest in sustainability provided incentives that made sustainability labelling commercially attractive. It also needs to be recognised that there is a degree of "chicken and egg" in these scenarios: Sustainability concerns create the conditions for regulation, which in turn draws further attention to sustainability concerns and increases social pressure. This may also be thought of as a ratchet effect and reinforcing changes.

In many of these historical accounts, socio-political dynamics are an important part of the transition process. These dynamics take a number of forms. In some cases peripheral groups join forces to advocate for policy and regulatory change or change in incumbent industry practice. In others, coalitions of interest are created to implement and monitor new sustainability practices, such as the WUE case or the cotton BMP approach. As societal values gradually change, more socio-political dynamics are illustrated by the way policy and market players have to alter their established positions, either through public policy measures such as regulatory measures or through new value chain practices such as sources and procurement practices.

In the case of foot and mouth disease (FMD) control in the Philippines (Box 5), a purposeful decision was taken to introduce regulation and co-investment with the private sector on the grounds that while this would benefit larger industry players, it would also deliver considerable social returns to poor rural households.

BOX 5. FMD ERADICATION IN THE PHILIPPINES

The eradication of FMD in the Philippines originated in results from publicly funded research and economic analysis, which, in 1999, provided “evidence” that FMD eradication would yield sufficient returns to expected costs, and therefore offered a worthwhile investment of public funds. The analysis also showed that while control and eradication would be beneficial to smallholder producers, a significant portion of the benefits would accrue to the large-scale commercial livestock sector. Eradication is not a one-off investment but requires continued investment to protect the FMD-free status of the country, once achieved. Sustained public funding of FMD surveillance and control would have been difficult to justify, particularly given the commercial orientation of the expected benefits. These results not only suggested that considerable scope existed for the government to involve the private sector more actively in financing national FMD control efforts, but also provided a platform for dialogue be-

tween the public and private sectors. This dialogue resulted in the direct participation of the commercial sector in the national FMD eradication task force and agreement on long-term complementary public- and private-sector investment in eradication and control activities and facilities. The system established and the subsequent eradication of FMD in 2011 continues to deliver productivity improvements, impacts to smallholders, and access to new markets for the livestock sector as a whole.

Source: Perry *et al.*, 2019.

A notable feature of the historical case studies is the specific effort that has been made to address the perverse consequences of transformation, particularly the environmental and social externalities. The early history of both the Chilean salmon and Australian cotton cases, for example, illustrate the way that economically powerful transformations came at significant social and environmental costs. Much of the system innovation discussed above in relation to these two cases is about how to redirect economic activity towards a more sustainable and socially responsible pathway. The Queensland WUE case study has some similar features. The difference is, however, that it was a prolonged drought that galvanized action to fundamentally change the way water was used for agricultural production. In these cases, the transformation was altering the nature of production systems, directing them to new environmental and social performance criteria.

While these cases in one sense illustrate a purposeful change in direction (a change in the directionality of innovation), it is also notable that crisis has been a triggering factor in what could be viewed as self-directed change. An example of crisis-driven change is the case of the Thai poultry sector. Here, the Thai company Charoen Pokphand Group has driven innovation in the poultry industry and is now the world's largest producer of cooked, chilled, ready-meal poultry products. This was achieved after the sector reorganized in response to an outbreak of HPAI in Thailand that resulted in the loss of key export markets. Like other transformational cases, the Thai export poultry case illustrates how earlier transformations that established new industries (in the 1970s) often need to transform once again to tackle global externalities – in this case HPAI.

The snapshot case studies describe a defined set of actions in the context of a wider change process that may (or indeed may not) be gaining momentum. In some cases, this involved pioneers pursuing sustainability and/or inclusive activities. For example, Sundrop Farms developed a sustainable production approach. While this cannot be described as a transformation of the agr-food system, it does illustrate the way the growing backdrop of sustainability awareness is increasing companies' interest in trying out new business models and the feasibility of doing so.

A number of snapshot cases studies deal with the development and promotion of specific technologies. The role of technology is discussed in detail below (with specific cases presented in brief in Boxes 6 to 10). As will be discussed, the technologies in these cases cannot be described as transformational, but instead are either a response to emerging market and social demands or an anticipated demand of a sustainable development pathway.

A key message from both the historical accounts and the snapshot case studies is that there is an interconnected set of changes across multiple levels of food systems involved in transition and transformation processes. Component innovation, like the snapshot case studies, is important, but it is the longer-term complex of processes and factors that bring about the deep changes or system innovations that will underpin the emergence of sustainable, inclusive agri-food systems. While it remains important that both the public and private sectors invest in snapshot interventions, this needs to be conceived as part of a much broader agenda of change where research and technology development are only one part.

4.12 THE ROLE OF TECHNOLOGY

A discussion of the role of technology in the case studies needs special attention because it has historically been a critical focus of innovation investment in the agri-food sector. This section also draws on the wider body of case studies, described in brief in Boxes 6 to 10, to illustrate the role and effectiveness of technology-driven approaches.

It is evident that research and technology played a key role in many of the case studies. Yet the role of technology is ambiguous, as both a driver and a response to the transformation process. In the cotton, Chilean salmon, and MSC cases, for example, technology was a response to the system innovation that was in play in the transition to sustainability. In other words, the system innovation both created demand for new technology and enabled its use by providing incentives and other enabling conditions. In other case studies, such as the East Coast fever (ECF) infection and treatment method (ITM) (Box 6) and the FMD eradication in the Philippines (Box 5), research provided evidence of the impact and benefit of changes to support decision-making that facilitates broader innovation.

BOX 6. EAST COAST FEVER INFECTION AND TREATMENT METHOD

Technological breakthroughs in the 1950s and 1960s led to a control measure commonly known as ITM against East Coast fever, a tick-borne disease of cattle caused by *Theileria parva*. The widespread deployment of ITM, however, was stalled for decades because key development and donor agencies focused resources and efforts exclusively on a frontier science research agenda rather than on the delivery of an existing solution. This resulted in an effective and simple control measure being sidelined by the search for recombinant vaccine solutions in a newly established international research centre that ultimately failed to produce the needed technological breakthrough. ITM received renewed attention when a public-private-sector partnership mechanism revisited the technology for field deployment and development impacts. The establishment of GALVmed by the United Kingdom's Department for International Development in the early 2000s, as a platform to engage the private sector in the commercialization of existing public science solutions, eventually formed sufficient political alignment and incentives to create an effective vaccine production and delivery mechanism. Over 1.5 million doses of ITM treatment have been administered in eastern and southern Africa.

Source: Perry and Dijkman, 2019.

Some of the case studies appear to be more technology-driven, or in some cases a single emblematic technology has become synonymous with apparently transformational change. For example, the treadle pump case study could be interpreted narrowly as the design and spread of an appropriate engineering solution. This it certainly was, but it was actually part of a much wider story of changing social relations in water markets and patterns of agrarian development more generally in Bangladesh.

Orange-fleshed sweet potato (OFSP), bio-fortified sweet potato varieties resulting from conventional plant breeding, is another example (Box 7). Studies suggest that OFSP has helped reduce vitamin A deficiency (VAD) in target areas. The case study, however, notes that for this to happen, the introduction of a new food-related technology needs to be coupled with considerable investment in value-chain development and public health messaging programmes. A similar food technology developed to reduce VAD – Golden Rice (GR) (Box 8) – but which is the result of gene transfer technology rather than conventional plant breeding, also received significant value-chain development and public health messaging support from a global consortium. However, its adoption continues to

be hampered by the controversy surrounding the use of genetically modified organisms (GMOs). This latter case is particularly illuminating of the way technology on its own cannot drive transformation without the coordination of enabling conditions and values across society to create what the literature refers to as a new "socio-technical regime".

BOX 7. OFSP IN SUB-SAHARAN AFRICA

VAD, a serious public health concern in many countries, can cause blindness and increase mortality. Breeding breakthroughs in the late 1990s in high-yielding OFSP varieties combined up to 50-fold increases in beta-carotene levels with drought tolerance and adaptation to local conditions. It was also identified that to combat VAD, these technological breakthroughs needed to be coupled with improved access to OFSP varieties and education to build awareness about the nutritional and health benefits of OFSP to improve the adoption, production and consumption of OFSP among rural households. Through the involvement of a major philanthropic foundation, significant investment has been directed to large advocacy and educational campaigns promoting household consumption of OFSP and associated value-chain development in countries where sweet potato is either the staple crop or an important secondary staple. To date, the primary evidence of OFSP impact comes from such interventions in Mozambique and Uganda, where investigation of scaling-up showed that the project led to OFSP adoption rates of 61 to 68% among project households, improved vitamin A knowledge at the household level and significantly increased (nearly doubled) vitamin A intake among targeted women and children.

Source: Lidder and Dijkman, 2019.

BOX 8. GOLDEN RICE

GR, a biotech invention dating back to 1999, promises to address VAD in the rice-consuming populations of Asia. The issue of GR as a suitable intervention for VAD has been conflated, however, with broader societal concerns and socio-political issues GMOs, food sovereignty and the future of agriculture in developing countries. It suffers from questions over legitimacy, and its framing as a scientific necessity and moral obligation by proponents of the technology has not been able to overcome societal values and the challenge of alternative solutions. At present the potential of GR to address VAD remains just that, a possible future option, as the science of crossing GR into local varieties and testing for efficacy and safety, the controversy around GMOs, and resistance to GR introduction in the target countries continue.

Source: Hays and Hall, 2019c.

Another way that technology-led approaches can play out is through commercialization pathways. For example, the case study on Novacq™ (Box 10) illustrates how careful selection of private sector partners and licensing arrangements can lead to the placement of a new product in the market with positive environmental benefits. However, as with the case of BARLEYmax™ (Box 9), this does not translate into transformation as neither of these products has been able to disrupt markets and create new regimes of consumer values and preference in a way that adds up to transformation. This is not to diminish the potential importance of the contribution of these technologies to the sustainability agenda; rather, the point is to underline the observation that a single technology on its own can rarely be considered transformational.

BOX 9. BARLEYMAX™

CSIRO is using advanced genetic technologies to create differentiated grain, food and feed products, which are either more productive or address growing consumer demand for healthy foods and ingredients. One of the outputs of nearly 20 years of research into cereal carbohydrates and nutrition has been the development of BARLEYmax™, a non-GM whole grain with enhanced nutritional benefits, including a low glycaemic index, twice the dietary fibre of regular grains and four times the resistant starch, which are indicated in supporting human health, such as reducing the risk of Type II diabetes and colorectal cancers.

Having developed a successful product, CSIRO worked with a range of collaborators to bring the first consumer product to market. The additional research capability developed, and the architecture of partnerships involved, has subsequently allowed the development and marketing of more complex nutritionally enhanced grains, opening up opportunities for growers and manufacturers beyond Australia and providing consumers with increased health food choices. Potential health and nutritional benefits related to the consumption of differentiated grain products have been estimated by one study to amount to about A$300 million to date.

Source: Hays and Hall, 2019d.

BOX 10. NOVACQ™

Novacq™ is a feed additive, developed by CSIRO, that reduces dependency on wild-harvest fishmeal for the global prawn farming industry. It emerged from 10 years of research on microbial systems associated with prawn nutrition that led to the development of a bioactive product that stimulates prawns' metabolic pathways. At the proof of concept stage CSIRO worked in partnership with an Australia aquaculture feed company to refine and commercialize the technology in 2013. The technology has subsequently been licensed to a Vietnamese company. The partnerships developed in this commercialization process have opened up a series of further research questions and commercialization opportunities for CSIRO and the companies. These partnerships continue and create the conditions for ongoing innovation in the future. While the benefits (economic and other) to date are relatively modest, an independent assessment of the value of Novacq™ suggests that it could increase prawn yields by 22%, and play a key role in reducing the aquaculture industry's reliance on marine protein for prawn feeds.

Source: Hays and Hall, 2019e.

4.13 ROLES AND CONTRIBUTION OF PUBLIC AGRICULTURAL RESEARCH ORGANISATIONS IN TRANSFORMATION PROCESSES

The case studies contain a number of different narratives of the role of public agricultural research. The first is a research-driven, technology-centric narrative, where public agricultural research organisations develop technology and thereafter promote this technology through commercialization or social marketing. Arguably, these cases have yet to fulfil their transformative potential. Case study examples include OFSP, Novacq™ and BARLEYmax™. (GR follows this modus operandi but has not yet reached farmers' fields.) Each of these cases has significant documented impacts that hold relevance to sustainability and social agendas. It would, however, be a stretch to label these as examples of transformation, because systemic changes in production and consumption systems have not been evident. As will be discussed further below, this is not to discount the importance of these technologies or of the contribution of public agricultural research to transformation. The problem is in the narrow scope of the case studies that were chosen and the questionable proposition that a single component technology can lead to agri-food system transformation.

The second narrative on the role of public agricultural research is a responsive research narrative where public agricultural research organisations develop technology, provide evidence, or propose other solutions as a response to a transformation process that is creating new performance criteria of production and consumption systems. In the case of cotton, for example, the transition to sustainability demanded seed-based technology that supported integrated pest management but also created incentives for the adoption and use of the new technology. Most of the case studies involve far less emblematic technologies than the Bt cotton varieties developed by CSIRO. The cotton case is also perhaps unusual in that it emerged from a highly effective and long-established relationship between a national science agency and the cotton industry that enabled appropriate technology responses.

Other case studies along these lines demonstrate how research responded to the needs of a sector throughout the transformation process. The Chilean salmon case demonstrates the way research delivered a wide variety of fish health and husbandry solutions, which complemented R&D and troubleshooting conducted by companies. The Queensland WUE case is similar. The coalition of interests around the drive for water use efficiency brought in researchers who already had long-standing expertise on the topic and a repertoire of solutions that could be quickly adapted and deployed. In all of these "responsive cases", it is the unpredictable unfolding of the transformation process that is demanding support from research at specific times.

A third narrative consists of evidence to support decision-making. In the Philippines FMD eradication case, for example, an initial economic research study made the case that co-investment in control measures with the private sector would also generate significant social benefits. Some of the evidence in this narratives comes from experimentation with institutional innovations. For example, in the cases on forage in Indonesia and East African dairy development, institutional experimentation explored how to strengthen sustainability or social impact when deploying suites of technologies. While these two cases have not resulted in transformation, they nevertheless illustrate the role of research in gathering evidence and lessons about the potential and limits of new sustainable development approaches that can then inform wider views and priorities in both public and private sector investment.

The fourth narrative is one of mobilizing existing research and technology, where the role of research organisations may be as a distant antecedent in terms of technology development, although other roles may be important. The case study of Sundrop Farms illustrates the way an entrepreneur was able to combine a range of "sustainability" technologies developed by both public and private research to develop a sustainable production system. A slight-

ly different twist to this narrative is the case study of the infection and treatment approaches to the management of the livestock disease ECF. This case study demonstrates that techniques and solutions developed by public researchers in the 1950s and 1960s did not come into their own until the 2000s, when the private sector was sufficiently well developed in East Africa to partner with public research to develop ways of deploying this technique.

The message from this last narrative is that the availability of a menu of sustainable and socially responsible technologies is critical in allowing transformation to proceed. This brings the story back to the technologies discussed in the first narrative of this section. On their own these technologies are not transformative. However, when system innovations emerge, for example in the case of Novacq™, to usher in more sustainable aquaculture practices in the prawn industry, the appropriate technology is available to support the new sustainability performance demands of the sector. BARLEYmax™ and OFSP can be viewed in a similar way as being in place to support system innovation in a shift to healthier diets, and in the case of OFSP, diets that specifically target the nutrient deficiencies of the poor. The case studies suggest that the availability of a menu of sustainable and socially responsible technologies is critical in allowing transformation to proceed, although demand for these technologies is difficult to predict. One of the roles of public agricultural research organisations is therefore to create a suite of technological possibilities that can contribute to new innovation trajectories of the future.

4.14 COMPARISON WITH OTHER SECTORS

By way of conclusion, it is useful to reflect on whether the patterns and experiences gleaned from these case studies from the agri-food sector are broadly similar to other sectors and particularly the in-depth examples included in Chapter 3: electric vehicles and wind power.

The general conceptualisation that emerged from the previous chapter seems to provide a good explanation of how transition and transformation processes are playing out in agriculture and food systems. The nested hierarchy of processes across scales is common, as is the importance of shifting patterns of alliances and political economy factors that typify changes in direction of the innovation trajectory. In both the agri-food and non-agri-food sectors, technology plays a critical role as both technology responses to demand and technical breakthroughs enable wider processes of change. For example, recent developments in battery technology have given fresh impetus to shift to electric vehicles rather than these technological breakthroughs being the trigger. In both the agri-food and non-agri-food examples, the transition/transformation focus – for example, low-emission vehicles and sustainably sourced fish – is framed by the larger-scale sustainability concerns of renewable energy and equitable, healthy food systems. These, in turn, are framed by global issues such as the need to respond to climate change and to achieve "zero hunger". This nesting of sustainable development issues seems to be common across sectors and hints at the convergence of challenges and pathways to sustainability.

These parallels reassuringly suggest that emerging analytical and policy framings relating to innovation for transformation in other sectors are relevant to the agri-food sector. There are, however, also a number of important differences that need to be recognised, some examples of which are given below:

- **The role of infrastructural change**. It appears that in the energy and transport sector examples, the role of infrastructure, related to a new socio-technical regime, is much more important than in the agri-food sector. This is not to underestimate the vital role of investment in transition-related infrastructure in agri-food systems, but in the examples of the energy and transport sector, it appears to be the fundamental precursor to the take-off and acceleration phase, whereas this is less prominent in the agri-food sector examples.

- **Social acceptability and social licence related to food**. Most products derived from agri-food systems are, directly or indirectly, consumed as food. As a result food safety and ethical concerns about food sourcing and technologies used in food production are additional dimension of the nature of agri-food system transformation. Social acceptability, or the social licence of a technology, thus becomes a fundamental part of any agri-food system transformation agenda

- **Dependence on biological systems**. Similarly, the agri-food sector, more than any other sector, depends on the use and modification of biological systems for its functions and outputs. This carries specific additional considerations related to the health and welfare impacts of changes in socio-technical regimes, both on the agricultural production side(e.g., the use of herbicides, pesticides and anti-microbials; animal welfare; zoonosis) and the consumption side (e.g., residues and antimicrobial resistance; zoonosis) of agri-food systems. The reliance on biological systems also means that compared with other sectors, the agri-food system requires specific forms of regulation and safeguards.

- **Importance for large numbers of poor people and food security**. Although the directionality of innovation is important to all sectors, the direct livelihood dependence on the agri-food sector of large numbers of poor and marginalized households in low – and middle – income countries makes this directionality particularly important. An added dimension of this is that sustainable development could divert food production to energy and industrial inputs. Balancing these types of trade-offs around the agri-food system will be a critical challenge.

- **The agri-food sector is subjected to technological advances that emerge in other sectors**. Increasing investment in the adaptation of ideas and technologies emerging from other sectors into agri-food systems creates significant potential for disruption. Given the broader sector's track record in terms of the exploitation of new technological developments in the past decade, this raises issues related to the adaptive capacity of the sector and its ability to effectively and efficiently integrate and exploit emerging technological advances.

- **Weak capacity of the agri-food sector to adapt**. In contrast to many other sectors, directionality has only relatively recently started to become a preoccupation within agri-food systems. In addition, innovation as a predictable process, with simple cause-effect relationships, continues to provide the framing for the way many development stakeholders engage with the transformation of agri-food systems. Consequently, the sector, in many regions and countries, currently lacks the necessary capacity, preparedness, and political economy to shift to more sustainable forms of governance.

4.15 IN SUMMARY

The purpose of the case studies presented in this chapter was to illustrate the features of transformation in agri-food systems. Many of the case studies have limitations, particularly when viewed through the definitional lens of transformation and sustainability transitions discussed in Chapter 3. Despite these limitations, it has been possible to gain a sense of what transformation looks like in the agri-food sector. In addition, the patterns and experiences shown in these case studies are broadly similar to those in other sectors, and they help explain the contribution of technology and innovation.

The picture that emerges is one of complex, long-term processes where new directions need to be widely agreed upon. This, however, leaves unanswered the question of how to navigate these diverse experiences – in particular, how to recognize and understand at what point in the transformation process current efforts are located and how to engage with different transformation processes and pathways. The next section presents a framework to address these questions.

5 THE EMERGING AND FUTURE CONTEXT OF PUBLIC AGRICULTURAL RESEARCH ORGANISATIONS

5.1 INTRODUCTION

This chapter returns to the core question of this study. Namely, based on the case studies and the analysis in the preceding chapters, what are the implications and challenges that public agricultural research organisations face through the reframing of innovation policy and practice by the sustainable development agenda? This chapter approaches this question by distilling from the previous chapters (i) the issues, processes and approaches that are becoming more important and that public agricultural research organisations are likely to need to pay greater attention to; and (ii) the dimensions of public agricultural research practice that are becoming increasingly problematic in light of the characteristics of agri-food system transformation highlighted by this study.

5.2 ISSUES, PROCESSES AND APPROACHES THAT ARE BECOMING MORE IMPORTANT

The discussion on the reframing of innovation and the illustrations from the case studies in the previous chapters suggest that the transformation and sustainable development agenda is creating a different context for all organisations involved in innovation and change processes. This in turn is raising concerns relating to the nature of transition and transformation processes and its dynamics, its governance and its stakeholders. Other concerns relate to society's increasing engagement in decisions around the direction of societal change. This rapidly changing context has a number of important practical implications. The following issues seem to be of particular importance and in need of greater attention and consideration by public agricultural research organisations:

5.2.1 Transformation as a deeply political process

Pathways to transformation are not only long, often covering decades, but also likely to be deeply political and contested because different actors will be affected in different ways and may stand to gain or lose (Meadowcroft, 2011; van den Bergh *et al.*, 2011; Patterson *et al.*, 2017). In the words of Geels (2002), "*System innovation is not just an innovation challenge, but also a deeply political project, which may affect vested interests from powerful incumbents.*"

In the same way, the choice of different pathways to different transformation outcomes cannot be considered apolitical. As a consequence a normative approach to transformation

is unlikely to succeed as it leaves the power dynamics in any particular context unquestioned and does not tackle the inertia that this is likely to exert on the pursuit of alternative pathways to sustainable and inclusive economic growth (Gillard *et al.*, 2016). Public agricultural research organisations have historically had a degree of unease around the political economy dimensions of innovation and change. The new context of transformation, however, suggests that ways will need to be found engage with the political economy of major change processes. This has far-reaching implications, and a number of the issues discussed below emanate directly from the socio-political nature of transition and transformation.

5.2.2 The increasing power of societies to articulate and leverage aspirations and patterns of societal acceptance

The increasing ability of civil society organisations to organise and mobilise public opinion and to advocate for policy, regulatory and market change is evident from many of the case studies. In a number of cases, the resulting changes in public opinion translate into political imperatives and messaging – for example, public policy statements on target setting in the electric vehicle case study and the changes in labour standards and environmental regulation in the Chilean salmon farming industry.

The increasing power of society is also playing out in shaping patterns of social acceptability. The case studies illustrate these so-called social licence to operate[3] issues in relation to technology acceptability. Specifically, GR, a GMO technology with the potential to contribute to the micronutrient status of millions of poor people, failed to gain the acceptance needed to be promoted and spread because of concerns about the safety of GMOs by parts of society. The public, private and philanthropic sector actors involved in the development and promotion of the technology failed to recognize and constructively engage with these concerns and unwittingly prevented its social acceptance and use.

The message here is not about the relative merits of GMOs. Rather the point is that the power of society to shape patterns of acceptance cannot simply be ignored. This is particularly so at a time of rapid bioscience advances where the manipulation of biological systems is seen as a new source of economic competitiveness as well as sustainability (see Box 11 on the bio-economy). For public agricultural research organisations, this means adopting approaches that actively engage society and a range of stakeholders in an open discussion about the economic, social and environmental consequences of new technologies and that help negotiate acceptable application pathways and regulatory regimes. Proactively contributing to the development of social licence for technology applications will thus be a critical role for public agricultural research organisations in the transformation agenda, and approaches such as responsible innovation will need to be given much greater consideration.

[3] A "social license to operate" refers to the level of acceptance or approval by local communities and stakeholders of organisations and their operations

BOX 11. EMERGING DOMAINS: THE EXAMPLE OF THE BIOECONOMY

Ongoing mainstreaming of the objectives enshrined in the 2030 Agenda for Sustainable Development is leading to the crystallisation of its principles in new economic and societal models that are changing demands on public agricultural research organisations. The bioeconomy is one example of such new economic and societal models.

The bioeconomy consists of the management of renewable biological resources and their conversion into a wide range of bio-based products via state-of-the-art technologies by using every part of the available biomass to its maximum sustainable potential in terms of both volume and value. The bioeconomy covers all kinds of products: energy, biofuel, heat, construction, bioplastics, smart packaging materials, food, livestock feed, textiles, health and pharmaceuticals, just to name few.

The bioeconomy is based on two main pillars: the use of renewable raw materials rather than fossil raw materials, and biobased innovation. The aim of the bioeconomy is therefore not only to replace fossil raw materials, but also to develop completely new products and processes. In so doing, it aims to contribute to and create the conditions for a closed, circular economy.

A growing understanding of global biological systems has led to a number of breakthroughs in the life and engineering sciences. The main focus of these activities is the benefits for humans and the environment. Research and development in research institutes and universities, start-ups, small and medium-sized enterprises and large-scale industry make important contributions to the development of a sustainable, internationally competitive economic system based on biological raw materials and processes. The idea is to apply new approaches along the entire value chain: raw material cultivation, process and product development as well as the recycling of residual materials.

A huge variety of methods and processes are used. The overall aim is to achieve a coupled and cascading use of biogenic raw material resources and residual materials. The main focus is on simple and combined chemical, physical and biotechnological and catalytic conversion technologies. Examples include new cultivation methods, biotechnologically produced fine and specialty chemicals and the use of algae for energy production or as a source for pharmaceuticals.

The creation of a bio-based economy requires processes and technologies that use biogenic raw and residual materials as the starting substrate, as well as bio-based processes that exploit the metabolic activities of living organisms such as microorganisms, bacteria or algae. In both cases, the goal must be to develop sustainable, flexible and cost-effective processes that can be scaled up quickly to industrial scale. As the situation stands, new and improved technologies and processes are being implemented mainly in pilot and demonstration plants. Further efforts are needed to transfer applications to an industrial scale.

Political framework conditions and social dialogue on the environment, climate and sustainability are forces that will continue to drive the transition to a bio-based economy. In recent years, the bioeconomy has become a key focus of political and technological interest both nationally and internationally. The European Commission, for example, states, "*Europe needs to make the transition to a post-petroleum economy. Greater use of renewable resources is no longer just an option, it is a necessity*." In its current EU research programme, Horizon 2020, the European Commission places the bioeconomy at the heart of its investment programme.

Source:
Kahn, 2014; Nordic Council of Ministers, 2017; Bioeconomy BW, n.d.; Gaia Group Oy, 2018.

5.2.3 Negotiated processes of determining future development pathways

The two issues highlighted above clearly indicate that unilateral decisions about future development directions and transformations are a thing of the past. The case studies show how alliances and unlikely groupings have been key to transformation success. The notion of negotiated futures captures the idea that there are critical process issues involved in developing joint and multiple visions of the future. The process bonus is that creating broad-based dialogues starts to build alliances to help implement this future, or at least to mitigate against vested interests blocking the change process. Public agricultural research organisations are unlikely to lead these dialogue processes, although they may need to catalyse them in cases where the absence of these dialogues may be hampering direction setting and prioritisation of research. More important is that public agricultural research organisations need to be engaged in these processes. This may involve undertaking analysis of future directions and scenarios that can inform debates about the long-term consequences of different decisions. It may also involve being an active participant in these society-level discussions and championing public good agendas around sustainability and related issues.

5.2.4 Engaging with pioneer activity to leverage niche sustainability experiments

The case studies highlight the critical importance of peripheral players in the early stages of transformation. Their role is to experiment and to demonstrate the viability of sustainable alternatives to industry and policy actors. The Sundrop Farms case study is an example of this. These peripheral players have the potential to disrupt dominant industry players and to catalyse wider changes in socio-technical regimes towards sustainability objectives. Increasingly, public agricultural research organisations are going to need to seek out these peripheral players and switch attention away from dominant market players. This will be particularly challenging in contexts where agricultural research organisations either depend on funding from existing industry players or where they operate in an institutional setting where responsiveness to the demands of industry is a key performance indicator.

5.2.5 Increasing prominence of complexity in sustainable development problem framing

The case studies highlight that the challenges facing agriculture and food systems in setting new directions are not isolatable problems, but rather a set of interlocking issues and drivers. The increasingly complex sustainable development context also has a direct impact on three other important issues. First, sustainability issues are multidimensional and pervasive and often call for **inter-sectoral solutions**. A number of the case studies such as Sundrop Farms (agriculture, energy, environment), the Chilean salmon industry (agriculture, environment, health, labour markets), and BARLEYmax™ (health and agriculture) provide clear examples of such sector straddling in the quest for sustainable solutions.

Second, enabling inter-sectoral solutions frequently calls for the **integration of sciences**. This does not mean that specific research inquiries in disciplines or sectors are not required, but that a greater challenge is how these are interwoven and integrated into processes at different levels. Calls for a shift to a transdisciplinary research approach around complex problems are not new (see, for example, Bammer, 2003). The transformation agenda reiterates the need for this to emerge as a core practice in public agricultural research organisations (see Box 12).

Third, in addition to the need to integrate across sectors, sciences, and disciplines, the increasingly complexity also means that public agricultural research organisations' relationships need to span stakeholder groups through **new nested, multi-stakeholder partnerships**. Collaboration choices and priorities will need to be made through the

lens of the innovation trajectories and transition pathways that these organisations wish to champion and the societal functions that they wish innovation to contribute to. Previous studies have suggested (ISPC, 2015) that this may also entail identifying and working with networks or groups of partners that have, or have developed, shared values – and dropping those that do not. Where society-level transformation is required, public agricultural research organisations need to embed themselves in networks, partnerships and new governance arrangements that are trying to advance sustainability on a number of fronts. It also means that where these organisations make decisions about specialization (for example, a comparative advantage in plant breeding), this will be relevant to transformation only if this activity is effectively embedded within an innovation environment – and partnership architecture – that can advance transformation and sustainability transitions at multiple levels.

These three implications underline the importance of adopting an agri-food system framing and a focus on agri-food system innovation as a way of defining the role of research and the pathways that connect research to the resolution of complex challenges defined by the sustainable development agenda.

BOX 12. DEFINITION OF TRANSDISCIPLINARY RESEARCH

Transdisciplinary research is, essentially, team science. In a transdisciplinary research endeavour, scientists contribute their unique expertise but work entirely outside their own discipline. They strive to understand the complexities of the whole project rather than one part of it. Transdisciplinary research allows collaboration in which exchanging information, altering discipline-specific approaches, sharing resources and integrating disciplines achieve a common scientific goal (Rosenfield, 1992).

5.2.6 The directionality of innovation

A key point of departure in the literature discussed in Chapter 3 is a concern not just for the speed of innovation but also for its direction (Steirling *et al.*, 2018). Calls for ways to improve the directionality of innovation have become more prominent – these calls apply in particular to design and implementation policies and approaches that foster the use of knowledge to create more inclusive impacts. Many of the issues and necessary implications discussed above relate implicitly or explicitly to this need to pay more attention to the directionality of innovation. In addition, directionality will require new practices such as the emerging practice of responsible research and innovation. Von Schomberg (2011) describes this as a research and innovation process that takes into account effects and potential impacts on the environment and society and provides the following definition:

> *Responsible Research and Innovation is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products, in order to allow a proper embedding of scientific and technological advances in our society.*

Already a number of initiatives are under way to develop responsible innovation practice in public research agencies (e.g., CSIRO, 2018). This would seem to be an important development at a time when disruptive innovation is likely to precipitate societal change and uncertainty, which if left unresolved can hinder the progress and innovation required for a shift to sustainable development.

5.3 DIMENSIONS OF PUBLIC AGRICULTURAL RESEARCH THAT ARE BECOMING MORE PROBLEMATIC

The discussion of the reframing of innovation and the illustrations from the case studies in the previous chapters suggests that transformation and the sustainable development agenda are making a number of dimensions of agricultural research practice increasingly problematic. In part, this relates to the diminishing relevance of some approaches in the light of the sustainability agenda. In other cases it relates to problematic assumptions that either no longer hold true or have not been supported with evidence and critically assessed and so are merely rhetorical.

5.3.1 Innovation systems not able to deal with directionality

In agricultural research practice the innovation systems perspective provided some much-needed new thinking (World Bank 2006, 2012) at a time when research organisations were struggling to find ways of connecting to impact processes (Hall, 2009). However, the discussion presented in Chapter 3 explains the limitations of this perspective in addressing the political economy and directionality of innovation trajectories. These limitations are particularly problematic in view of the "transformation of systems" agenda of the SDGs and sustainable development more generally. Chapter 3 suggests the system innovation perspective as a successor to innovation systems. Agricultural research organisations are going to need to continue to structure their engagement with innovation processes by recognising the network of interacting players, processes, and policies that condition both the use and demand for research. In other words they need an innovation systems framing. However, safeguards and frameworks will need to be developed to help ensure that research is responding to and supporting desirable innovation trajectories and societal functions rather than helping reproduce existing undesirable directions or being captured by the vested interests of incumbent industries and market players. It is urgent to develop practices that help agricultural research organisation work within and contribute to system innovation rather than making piecemeal contributions.

5.3.2 Scaling logic not adapted to system innovation

Scaling continues to be a major area of concern for public agricultural research organisations and their funders. However, much of current logic comes from a "multiplication" scaling tradition rather than from a system innovation tradition that characterises transformation. In the former tradition, scaling is understood as the spread of technologies and practices and is determined largely by the adoption behaviour of farmers, firms and consumers. A slightly more nuanced version of this concept makes the distinction between out-scaling (the diffusion and spread of technologies) and up-scaling (the influences on policies that help replicate interventions that promote adoption).

The systems innovation tradition presents a scaling logic with bottom-up processes of change driven by changing societal needs, and top-down processes of change driven by changing policy incentives and regulation. Frequently, there is a dynamic interplay of drivers across scales, with new technology acting either as a disruptive force or as a response to new social, environmental and economic imperatives. The consequence of this characteristic is that multi-scale change processes involve multiple stakeholders, and transformation involves numerous alliances and collaboration to orchestrate the integration of various institutional and technological dimensions of the innovation process.

The scaling process thus needs to be understood as an interlocking set of adaptations that range from individuals to the entire "system of use" or socio-technological regime. This scaling logic involves a joined-up process of negotiating a coherent set of changes to create new systems, including a system of use for new technologies. A key feature of scaling in this logic is processes that lead to the emergence of broad-based agreement on the

balance of economic, social and environmental performance of the system and the purpose for which technologies are being developed and deployed. Public research organisations are going to need to recast this new scaling logic into their impact narratives and engage funders in a discussion of the new nature of scaling and the expectations and time frames that this entails. A useful starting place would be to embrace the notion of agri-food system innovation to flag the recognition of an underpinning theory of change that is systemic in nature.

5.3.3 Unrealistic assumptions about the role of the private sector

The spread of innovation systems ideas in the last decade or so has created the impression that partnership with the private sector is central to driving innovation. While it is certainly true that the private sector is a critical actor in innovation processes, the case studies also show that public investment needs to provide a range of incentives, infrastructure and support that reduce the risk for subsequent private sector investment. A recent review of evidence on the role of the private sector in promoting nutrition in South Asia concludes that it is unrealistic to assume that the private sector will have a substantial role (Gillespie *et al.*, 2019). This speaks to a greater concern that the public sector needs to be more proactive in driving sustainability and simply cannot devolve responsibility to the private sector, particularly in the early stages when new sustainable trajectories are being developed.

5.3.4 Misleading technology-centric narratives of transformation

Research and technology played a key role in many of the case studies. Yet the role of technology is ambiguous, as both a contribution and a response to the transformation process. The overall picture that emerges from the case studies, however, is that technology never acts alone as a force for change. Its use is always embedded in a wider process of industry and societal change where practices, capabilities regulation and societal values play a critical role. In the same way, the case studies illustrate that technologies with sustainability or inclusive properties and characteristics have no meaning unless these wider sets of conditions are in place, and this often involves a long process of adaption of systems of use. The directionality of innovation is thus a socio-political phenomenon, not a technological phenomenon. In other words, there are transformational process of innovation that deploy new technologies, but these technologies in and of themselves are not transformational.

This is challenging for public agricultural research organisations whose success narratives are intertwined with iconic technologies developed. Extending these narratives to the notion of transformational technology is highly misleading, as are efforts to assess the transformative potential of technology through a purely technological lens (for an example of the latter, see Herrero *et al.*, in preparation). While clearly technology development remains a core task for public agricultural research organisations, recasting impact narratives around systemic change is going to be more productive than perpetuating a myth that technology alone can provide the solution to the sustainability conundrum.

5.3.5 Funding cycles poorly aligned with the transformational agenda

Public agricultural research organisations around the world face two pressures that make purposeful directionality challenging: shrinking public funding – and the search for revenue sources including the private sector – and a funding environment skewed toward short-term rather than long-term impacts. The international literature has concentrated on the identification of relative expenditures by the private and public sector and their potential contribution to public goods (e.g., Fuglie *et al.*, 2011; Fuglie *et al.*, 2012). Data from this literature show that private spending tripled between 1990 and 2014 (Fuglie, 2016) and that in high-income countries this now constitutes the main investment in agricultural research. Evidence from other analyses also indicates that public R&D, unlike private

research investments (Beintema and Stads, 2017), focusses more on issues and crops with smaller potential returns (Reynolds *et al.*, 2017). In line with the private sector, however, most public and philanthropic agricultural research investments still target commodity grains and cash crops (Anderson *et al.*, 2017).

While a conversation about levels of funding for agricultural research is undoubtedly important, their fluctuation is nothing new. The more recent boom and bust cycles in public funding, combined with an ongoing transition from longstanding fungible core funding to short-term competitive grants are, however, providing new challenges. Studies have shown that long-term, secure funding has a larger impact on agricultural productivity than do competitive grants, as steady funding can support core or foundation research, as well as higher-risk, longer-term research of national importance (Monke, 2016). Moreover, with funding tight, investigators tend to pursue safe projects rather than less fundable ones with uncertain but potentially path-breaking outcomes (Stephan, 2015).

The case study work presented here provides additional evidence that current support to innovation in agri-food systems is best suited to incremental innovation and impact (see case study on fodder in Indonesia and on East Africa dairy hubs; see also findings in ISPC, 2015). Discussion of these findings during multi-stakeholder workshops that accompanied this study acknowledged that historically derived path dependencies shape the way research organisations and other stakeholders engage in the debate and practice of agri-food system innovation, making it difficult to follow more transformational pathways of innovation (CSIRO and CGIAR ISPC Secretariat, 2016, 2017). While this is an issue that is difficult for public research organisations to change, it does mean that hard decisions will need to be taken in terms of the types of project funding that are accepted, where the criteria for acceptance relate to a project's potential to contribute to an articulated and realistic pathway to transformation.

5.3.6 The absence of an evidence base for many agricultural transformation stories

One common element in the snapshot and technology types of case studies is that, while they are recognised by different stakeholder groups as examples of transformational change, confirming evidence appears to be lacking. As acknowledged in Chapter 4, some of the cases may in the future become part of a wider transition to sustainable agri-food systems. However to date, these cannot be labelled as examples of transformation because systemic changes in production and consumption systems have not been evident. Not only does this raise questions about the much-needed interrogation of these unsubstantiated success stories, but it also points to a more serious issue. Specifically, in the absence of better evidence on how public agricultural research can best be organised to contribute to innovation for transformation, it will be difficult to stimulate and justify the institutional changes necessary to reposition public agricultural research organisations in the emerging transformation scenario.

5.3.7 Incremental biases in current evaluation and impact assessment traditions

Donor organisations must provide evidence of impact in order to justify funding allocations and thereby position themselves for future allocations. This puts priority on projects for which results can be relatively easily measured. And when, in addition, political or bureaucratic requirements stipulate that resources can be committed for only short periods – often only a single year – this further prioritizes projects that generate very near-term results. To give a sense of certainty to decision makers, this situation also leads to project proposals packaged with often unrealistic log-frames and over-quantified milestones, often defined on the basis of incremental change. Each of these factors mitigates against support to the longer-term and more uncertain investments that are the foundation of most transformational change processes.

The need to show early results in order to secure future funding can also compromise learning functions within donor agencies. Too often priority in monitoring and evaluation is placed on generating "good news" results that can be used to prove or demonstrate rather than test, impact and "market" a project within the donor agency and oversight bodies. Favourable reports are also useful for career advancement at multiple levels within a mission or agency department. The result is that critically important strategic and tactical lessons that can be gleaned from dead-ends and outright failures are inadequately identified and analysed, leading to breakdown in adaptive management practices that are essential when investing in transformational change processes.

5.3.8 Towards an agri-food system innovation framework

The above sections distilled a range of issues that public agricultural research organisations are facing because of the emerging transformation agenda and its emphasis on agri-food system innovation. This still leaves unanswered the question of how to navigate these diverse experiences. In particular, at what point in the transformation process are current efforts located, and how should different organisations and particularly public agricultural research organisations engage with different transformation processes and pathways?

To move towards answering those questions, the next sections present a framework referred to as the agri-food system innovation framework. The purpose of this framework is to help understand different transformation situations and make decisions about courses of action that can advance transformation and sustainability transitions.

Figure 7 and the description below provide a heuristic to help understand the types of transformation situations that are being encountered and how best to engage in these situations to promote transformation and sustainability transitions. The framework is targeted at public agricultural research organisations but is equally relevant to other stakeholder groups that need to navigate this territory and wish to contribute to transformations that support sustainable and inclusive growth.

The framework comprises the following elements:

- Four quadrants, each of which represents different innovation environments that shape the dominant innovation trajectory in agri-food systems.
- Four scales, each of which represents a different performance measure of the agri-food system.
- Four transformation pathways, each of which represents a different pathway between the innovation environment quadrants.
- A boundary between the different quadrants that respects changes in factors that shape innovation action and enable the shift from one innovation trajectory quadrant to another.

The ***four innovation environments*** quadrants are as follows:

Incremental innovation. This environment reproduces and maintains an existing innovation trajectory. Incremental innovation is taking place, but the production and consumption systems remain largely unaltered. It is characterised by optimization within the existing system, with limited agri-food system adaptation.

Incumbent innovation-driven transformation. This environment generates a new innovation trajectory and system innovation that transforms the production and consumption system. The environment is, however, bounded by the interests of incumbent players, and the direction of the dominant development or growth pathways remains unaltered. It is characterised by the dominance of economic growth as the key performance indicator.

Experimental discontinuity. This environment allows space for numerous niche innovations and for

the piloting of new production and consumption systems, generally by peripheral players. These niches are a discontinuity in the dominant innovation trajectory, but only constitute early experimentation of a shift to a new innovation environment.

Sustainability transitions. This environment supports a discontinuous shift to a new innovation trajectory and production and consumption system. The environment is characterised by values, incentives and regulations that balance economic, social and environmental performance.

The ***four scales*** are as follows:

Economic performance and impact. This measures the scale of economic impacts delivered by the dominant agri-food system in different innovation environments.

Social and sustainability performance and impact. This measures the scale of social and sustainability impacts delivered by the dominant agri-food system in different innovation environments.

Systems adaptation. This measures the scope of system innovation in agri-food systems in different innovation environments on a scale ranging from system optimization to system transformation.

Stakeholder alliances and value networks. This measures the extent to which patterns of alliances and value networks are changing in the transition between different innovation environments on a scale from "stable" to "reconfigured."

The ***four pathways*** in the framework and the boundary conditions that reframe innovation to trigger the shift to a different innovation environment are as follows:

System responses to economic opportunities. Innovation action is reframed by competition, new technology, cost-saving pressures and changing demand and supply conditions. This encourages companies to use innovation to maintain market share by the application of new technology or business models. The reframing of innovation action in this way facilitates a shift from an incremental innovation regime to an incumbent transformation environment, which in turn opens up opportunities for new waves of incremental innovation in the new production and consumption system created.

System responses to social and political drivers. Innovation action is reframed by loss of social licence, environmental crises, technological and business changes, and/or policy and regulatory changes. This drives a change in the direction of the innovation trajectory, creates a balance between economic and sustainability objectives and supports a transition to an agri-food system with sustainable production and consumption systems.

System responses to niche pressures. Innovation action is reframed by "entrepreneurial state"[4] investments, technological change, (re)alignment of stakeholder interests, changing consumer demands and/or through futures that are negotiated and endorsed through societal dialogues. This creates new, discontinuous innovation trajectories in the agri-food system that break path dependency and support a transition to sustainable production and consumption systems.

New waves of incremental innovation unleashed by sustainability transitions. Having reframed innovation action in the direction of sustainability and created new innovation trajectories, this pathway opens up new opportunities for incremental innovation in the agri-food system.

[4] In an entrepreneurial state, economic success is a result of public and state-funded investments in innovation and technology, rather than a result of the small-state, free-market doctrine that often receives credit for a country's strong economy (Mazzucato, 2013).

5.4 APPLYING THE FRAMEWORK

Like a number of similar frameworks of this format (see for example the Cynefin Framework of Kurtz and Snowden, 2003), the purpose of the agri-food system framework is to aid decision-making by providing an imprecise but practical way of categorizing contexts and strategies or courses of action appropriate to these different contexts.

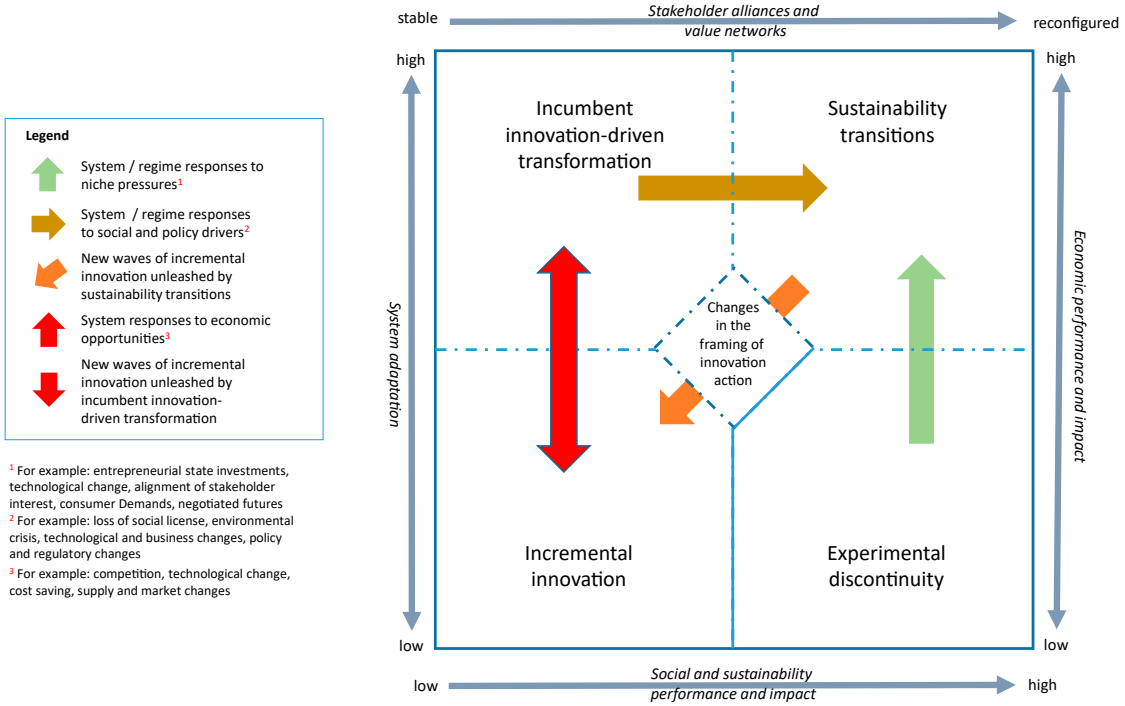
In the agri-food system innovation framework, the contexts are the innovation environment quadrants and the courses of action are the pathways that link the quadrants and the types of actions and investments appropriate to achieving different outcomes on the four scales. An additional aspect of the framework is that it helps navigate the shift from the "least desirable" (in terms of sustainability transitions) bottom left-hand quadrant to the "idealized" top right-hand quadrant.

The need for this type of tool emerged from this study's experience of trying to collect, and make sense of, case studies on agri-food system transformation. In the absence of a detailed examination of each case, it was found to be extremely difficult to categorize the type of transformation process at play, to assess its directionality, to judge its stage of maturity and to ascertain whether it was a minor evolution in existing arrangements or a genuine discontinuity of the innovation trajectory. Figure 8 maps the 16 case studies onto the framework to illustrate how it can be used to gain an understanding of the type of innovation and transformation process encountered.

Being able to understand the context is important for stakeholders, including public agricultural research organisations, because it can inform judgements about how to respond to existing conditions.

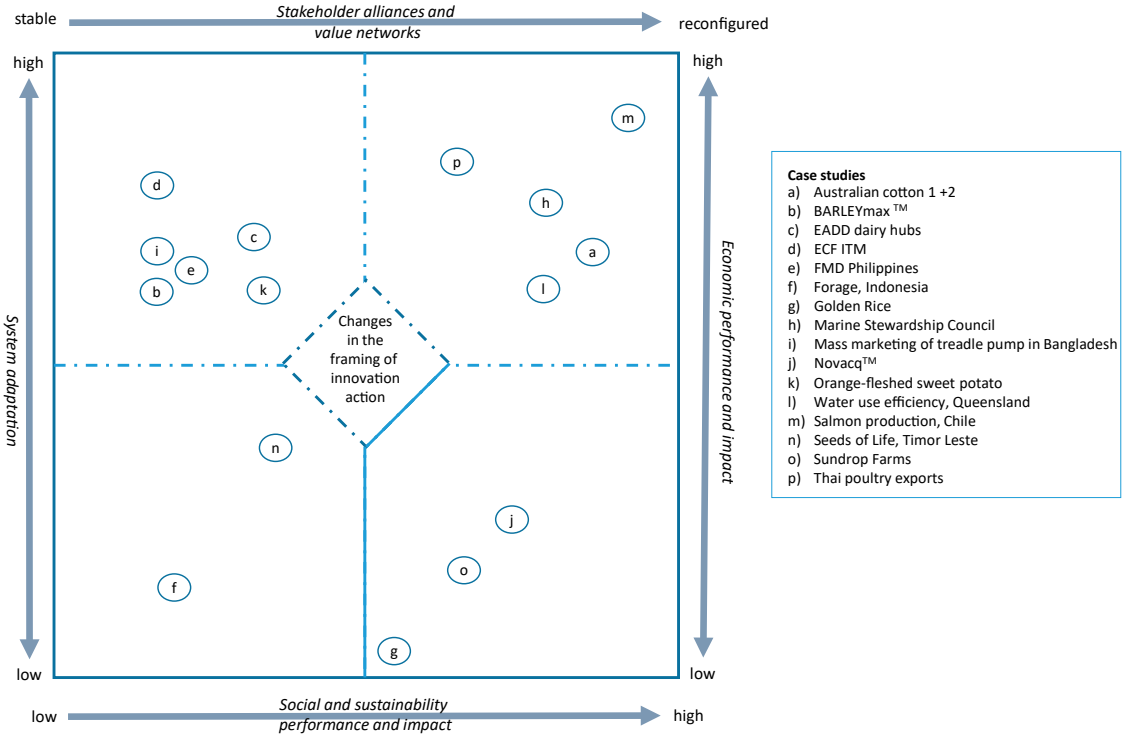
For public agricultural research organisations, context provides a lens to reveal where current activities fit into the transformation landscape. It helps identify what other conditions and alliances will be needed to leverage the contribution of research to innovation for transformation. It provides a way of making judgements about how different ways of engaging with transformation relate to the quality and scale of impact and thus the extent to which different ways of engagement are aligned with the SDGs. In addition, it clarifies where public agricultural research organisations should take a leading role and where they should play a more responsive role, or, alternatively, play a neutral role providing evidence to inform other stakeholders' decisions and directions. The framework also provides a way of understanding how scaling takes place in relation to systemic change of the type envisaged by the SDGs.

Figure 7. Agri-food system innovation framework



Source: Authors.

Figure 8. Case studies mapped onto the agri-food system innovation framework



Source: Authors.

6 IMPLICATIONS FOR THE CGIAR

The CGIAR already has a strong directionality narrative. It is enshrined in its commitment to poverty reduction and food and nutritional security of the world's poorest and flagged by an explicit ambition to contribute to the SDGs. Based on this study, and the issues outlined in the previous chapter, what else should the CGIAR consider in the era of transformation?

The discussion in Chapter 5 has pointed to some areas where public agricultural research organisations may need to adapt in response to the emerging innovation landscape. It is not, however, possible to prescribe how different organisations should go about this process of adaptation as this will be specific to each organisation and the context in which it is situated. The observations in this final section directed at the CGIAR system similarly recognize that responses to the transformation agenda need to play out within the specific context of the CGIAR. To guide this process, this study suggests that the CGIAR needs to develop four new narratives that frame critical areas of its activities and role. The process of elaborating these narratives through consultations and strategic conversations with stakeholders, including donors, could be a critical step for the CGIAR in garnering the financial and operational support for a central role in the emerging transformation agenda.

6.1 A NEW SCALING AND IMPACT NARRATIVE

The current narrative of scaling and impact is inadequate to frame CGIAR engagement with innovation for transformation. It currently struggles to accommodate an impact pathway where system innovation unlocks new opportunities for deploying existing and future research findings and technological developments. It struggles to accommodate an impact pathway where the capacity of systems to innovate in response to the new sustainability agenda is key to driving change processes. It struggles to accommodate impact pathways that are multi-scale in nature. Moreover, it struggles because the current narrative makes unreasonable assumptions and expectations about the role and responsibilities of the CGIAR in relation to achieving impact. A new scaling narrative is important because it signals a theory of change that more accurately reflects the system innovation nature of the transformational change agenda of the SDGs and that more realistically reflects the CGIAR's role and comparative advantage as a science organisation. Coming to terms with the implications of the agri-food system innovation perspective will be key to the development of this new narrative.

6.2 A NEW PARTNERSHIP AND VALUE NETWORK NARRATIVE

The CGIAR has at least a decade of efforts behind it to develop a partnership strategy suited to the contemporary development scenario (ISPC, 2015). Public-private partnerships are still an area of contention and remain wrapped in a simple narrative of private delivery of CGIAR technology. Innovation for transformation reframes how the CGIAR engages in partnerships and the narrative it presents to enact these partnerships. There are number of issues here. First, not all partnerships are aligned with the sustainability agenda, and not all existing partnerships are going to be useful for transformation. The directionality issues in transformation mean that the CGIAR will need to link into value networks that are committed to advancing the sustainable development agenda and are committed in both policy and practice to transformational change. This approach may call into question the role that the private sector is willing and able to play in sustainable development. This may also mean establishing or joining new partnerships that align around the big issues that can create coalitions of interest needed to drive system innovation rather than only transactional partnerships aimed at getting projects implemented.

The priority is to develop a partnership narrative centred on agri-food system innovation and shared values. This will need to involve new and different partners in the private and public sectors and, as previous ISPC studies have suggested, a different architecture. Donors will also need to be scrutinized. CGIAR centres need a narrative that makes explicit their intention to partner with donors that are committed to transformational change in the sense defined by this study. While the purpose here is not to be prescriptive about what new partnership and value network narratives should look like, couching these narratives in line with the agri-food system innovation and transformation agenda will be critical.

6.3 A NEW SOCIAL LICENCE NARRATIVE

Agriculture and new technology are globally at risk of losing their social licence to operate. Part of the transformational agenda is the development of production and consumption systems that are sustainable and socially acceptable. The CGIAR does not seem to have a narrative that addresses this and has thus far largely shied away from, for example, the controversies around GMOs. Going forward, it needs to have a much clearer understanding of the economic, social and environmental dimensions of new generations of platform technologies and a narrative to frame its engagement with these.

6.4 A NEW SCIENCE NARRATIVE

The 20th century was the century of discipline-led improvement of agricultural productivity. The innovation for transformation agenda implies a much more complex problem set, needing a great use of multi-disciplinary and trans-disciplinary science approaches. It also implies integration across sectoral interests including agriculture, food, health, energy and infrastructure. It is not yet entirely clear what the new science agenda in the innovation for transformation agenda will look like or how it will address trans-disciplinarity and the role of social and systems sciences in the innovation process. Nevertheless, a key priority should be developing this new narrative as it frames how science advances are to be exploited and what new capabilities will need to be built.

6.5 A VISION OF THE CGIAR AS A CHAMPION OF DIRECTIONALITY OF INNOVATION

Of course, large and long-standing organisations, like the CGIAR, have strong path dependency, and adapting to the increasingly prominent transformation agenda will raise some challenges. Periods of disruption, however, can also present critical opportunities for reinvention. The recent fate of

libraries is a useful illustration. In the era of the internet, libraries as places to access books and scientific literature have become largely redundant. Many public libraries have closed or are struggling to justify their existence. Those that have survived and prospered are those that have realized that libraries are no longer just about books, but about public spaces to share information (shared workspaces, workshop venues, etc.).

Rethinking the CGIAR in this way points to an exciting opportunity. The CGIAR is not a genetic improvement organisation per se, although that has been, and remains, one of its key science entry points and specialization. The core values and strategic intent of the CGIAR, however, could be more accurately interpreted through its role as the custodian of an agricultural science agenda that serves contemporary global development ambitions and as a champion of the directionality of innovation towards that end. In the early years of the CGIAR, this was about producing more food, particularly in countries that at that time were considered underdeveloped. Over the years, this agenda has become more nuanced to include food security, poverty reduction, and coping with climate change.

The current global development agenda is about transformational change and in particular the sustainability transitions of agri-food systems, and of society as a whole. Today, there is no international player explicitly acting as the custodian of an international science agenda that supports the transformational ambitions of the agricultural and food sectors and that works to ensure the directionality of agri-food system innovation. The CGIAR could occupy this role. Such a role aligns with its core values and strategic intent. It would re-emphasize its globally important role and in doing so reinvigorate political and financial support. It would also help build new capacities at a time when global development is at a critical point of inflection and in need of proactive investments in public goods.

6.6 IN CLOSING

This study not only indicates that transformation is here to stay, but also provides a clear indication of the numerous challenges that public agricultural research organisations will encounter as they work to remain relevant in this era. It will not be easy for the CGIAR to navigate the different innovation environments and transformational pathways to ensure its contribution to the SDGs. At the same time, however, the transformation agenda offers a tremendous opportunity for the CGIAR to regain its leadership position as the custodian of an agricultural science agenda that serves contemporary global development ambitions and as a champion of the directionality of innovation towards that end. Being proactive and developing the new narratives suggested by this study may assist the CGIAR in taking steps towards seizing that opportunity.

REFERENCES

Allen, T., Heinrigs, P. and Heo, I. (2018). *Agriculture, Food and Jobs in West Africa*. West African Papers, No. 14. OECD Publishing, Paris.

Anderson, C. L., Reynolds, T., Biscaye, P. and Callaway, K. (2017). *Funding for Agricultural Research and Development Public Goods*. EPAR Technical Report #339. Evans School Policy Analysis and Research Group (EPAR), University of Washington, Seattle.

Arthur, W. B. (1983). *On Competing Technologies and Historical Small Events: The Dynamics of Choice under Increasing Returns*. IIASA Working Paper WP-83-090. International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.

Arthur, W. B. (1994). *Increasing Returns and Path Dependence in the Economy*. University of Michigan Press, Ann Arbor.

Bammer, G. (2003). *Embedding Critical Systems Thinking and Other Integration and Implementation Sciences in The Academy*. Stream 13: OR/Systems Thinking for Social Improvement. Australian National University, Canberra.

Battersby, J. (2017). Food System Transformation in the Absence of Food System Planning: The Case of Supermarket and Shopping Mall Retail Expansion in Cape Town, South Africa. *Built Environment*, 43 (3), pp. 417–430.

Beintema, N. and Stads, G. J. (2017). *A Comprehensive Overview of Investments and Human Resource Capacity in African Agricultural Research*. ASTI Synthesis Report. Agricultural Science and Technology Indicators, International Food Policy Research Institute, Washington, DC.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S. and Rickne, A. (2008). Analyzing the Functional Dynamics of Technological Innovation Systems: A Scheme of Analysis. *Research Policy*, 37 (3), pp. 407¬–429.

Bijker, W. E., Hughes, T. P. and Pinch, T. J. (1987). *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*. MIT Press, Cambridge, MA.

Bioeconomy BW. N.d. What Is a Bioeconomy? https://www.biooekonomie-bw.de/en/bw/definition/.

Carlsson, B. and Stankiewicz, R. (1991). On the Nature, Function and Composition of Technological Systems. *Evolutionary Economics*, 1 (2), pp. 93–118.

Caron, P., Ferrero y de Loma-Osorio, G., Nabarro, D. et al. (2018). Food Systems for Sustainable Development: Proposals for a Profound Four-Part Transformation. *Agronomy for Sustainable Development* 38 (4): 41. https://doi.org/10.1007/s13593-018-0519-1.

Chang, R. D., Zuo, J., Zhao, Z. Y., Soebarto, V., Zillante, G., and Gan, X. L. (2017). Approaches for Transitions towards Sustainable Development: Status Quo and Challenges. *Sustainable Development*, 25 (5), pp. 359–371. https://doi.org/10.1002/sd.1661.

Cirera, X. and Maloney, W. F. (2017). *The Innovation Paradox: Developing-Country Capabilities and the Unrealized Promise of Technological Catch-Up*. World Bank, Washington, DC. https://doi.org/10.1596/978-1-4648-1160-9.

CSIRO (Commonwealth Scientific and Research Organisation). (2018). Responsible Innovation Initiative. https://www.csiro.au/en/Research/LWF/Areas/Responsible-Innovation.

CSIRO and CGIAR ISPC Secretariat. (2016). *Agri-Food Systems Innovation: Pathways to Impact: Resetting the Agri-Food Systems Innovation Conversation*. Canberra and Rome.

CSIRO and CGIAR ISPC Secretariat. (2017). *Agri-food System Innovation: Reframing the Conversation*. Workshop Report. Canberra and Rome.

Dahmen, E. (1989). "Development Blocks" in Industrial Economics. *Scandinavian Economic History Review*, 36 (1), pp. 3–14.

Darnhofer, I. (2015). Socio-Technical Transitions in Farming: Key Concepts. In Sutherland, L., Darnhofer, I., Wilson, G. and Zagata, L., eds., *Transition Pathways towards Sustainability in Agriculture: Case Studies from Europe*. CABI, Wallingford, UK. https://doi.org/10.1079/9781780642192.0017.

Development Initiatives (2018). *2018 Global Nutrition Report: Shining a Light to Spur Action on Nutrition*. Bristol, UK.

Dijk, M., Orsato, R. J. and Kemp, R. (2013). The Emergence of an Electric Mobility Trajectory. *Energy Policy*, 52, pp. 135–145.

Dijkman, J. (2019a). Marine Stewardship Council. In Kelly, J., ed., *Public Agricultural Research and Development in an Era of Transformation: The Challenge of Agri-Food System Innovation*. Resource Document I: Case Studies. CGIAR Independent Science and Partnership Council (ISPC) Secretariat and Commonwealth Scientific and Industrial Research Organisation (CSIRO), Rome and Canberra, pp. 62–71.

Dijkman, J. (2019b). Thai Poultry Exports. In Kelly, J., ed., *Public Agricultural Research and Development in an Era of Transformation: The Challenge of Agri-Food System Innovation*. Resource Document I: Case Studies. CGIAR Independent Science and Partnership Council (ISPC) Secretariat and Commonwealth Scientific and Industrial Research Organisation (CSIRO), Rome and Canberra, pp. 123–134.

Dolata, U. (2009). Technological Innovations and Sectoral Change: Transformative Capacity, Adaptability, Patterns of Change: An Analytical Framework. *Research Policy*, 38 (6), pp. 1066–1076.

Dosi, G. (1982). Technological Paradigms and Technological Trajectories. *Research Policy*, 11 (3), pp. 147–162.

Edquist, C. (1997). Systems of Innovation Approaches: Their Emergence and Characteristics. In Edquist, C., ed., *Systems of Innovation: Technologies, Institutions and Organizations*. Pinter, London.

FAO (Food and Agriculture Organization of the United Nations). (2017). *The Future of Food and Agriculture: Trends and Challenges*. Rome.

FAO. (2018). *Transforming Food and Agriculture to Achieve the SDGs: 20 Interconnected Actions to Guide Decision-makers*. Rome.

FAO, IFAD (International Fund for Agricultural Research), UNICEF, WFP (World Food Programme) and WHO (World Health Organization). (2018). *The State of Food Security and Nutrition in the World 2018: Building Climate Resilience for Food Security and Nutrition*. FAO, Rome.

Farla, J., Markard, J., Raven, R. and Coenen, L. (2012). Sustainability Transitions in the Making: A Closer Look at Actors, Strategies and Resources. *Technological Forecasting and Social Change*, 79 (6), pp. 991–998. https://doi.org/10.1016/j.techfore.2012.02.001.

Freeman, C. (1982). *The Economics of Industrial Innovation*. University of Illinois at Urbana-Champaign's Academy for Entrepreneurial Leadership Historical Research Reference in Entrepreneurship. https://ssrn.com/abstract=1496190.

Freeman, C. (1988). Japan: A New National System of Innovation? In Dosi, G., Freeman, C., Nelson, R., Silverberg, G. and Soete, L., eds., T*echnical Change and Economic Theory*. Pinter, London.

Fuglie, K. (2016). The Growing Role of the Private Sector in Agricultural Research and Development Worldwide. *Global Food Security*, 10, pp. 29–38.

Fuglie, K., Heisey, P., King, J., Pray, C. and Schimmelpfennig, D. (2012). The Contribution of Private Industry to Agricultural Innovation. *Science*, 338 (23 November), pp. 1031–1032.

Fuglie, K., Heisey, P., King, J., Pray, C., Day-Rubenstein, K., Schimmelpfennig, D., Wang, S. and Karmarkar-Deshmukh, R. (2011). *Research Investments and Market Structure in the Food Processing, Agriculture Input and Biofuel Industries Worldwide*. Economic Research Report 130. Economic Research Service, U.S. Department of Agriculture, Washington, DC.

Gaia Group Oy. (2018). *Innovation Ecosystems in a Sustainable Bioeconomy: A Finnish Case Study for OECD*. Helsinki.

Geels, F. W. (2002). Technological Transitions as Evolutionary Reconfiguration Processes: A Multi-Level Perspective and a Case-Study. *Research Policy* 31 (8–9), pp. 1257–1274. https://doi.org/10.1016/S0048-7333(02)00062-8.

Geels, F. W. (2004). From Sectoral Systems of Innovation to Socio-Technical Systems: Insights about Dynamics and Change from Sociology and Institutional Theory. *Research Policy*, 33 (6–7), pp. 897–920. https://doi.org/10.1016/j.respol.2004.01.015.

Geels, F. W. and Kemp, R. (2007). Dynamics in Socio-Technical Systems: Typology of Change Processes and Contrasting Case Studies. *Technology in Society*, 29 (4), pp. 441–455. https://doi.org/10.1016/j.techsoc.2007.08.009.

Geels, F. W. and Schot, J. (2007). Typology of Sociotechnical Transition Pathways. *Research Policy*, 36 (3), pp. 399–417.

Geels, F. W., Kern, F., Fuchs, G., Hinderer, N., Kungl, G., Mylan, J., Neukirch, M., and Wassermann, S. (2016). The Enactment of Socio-Technical Transition Pathways: A Reformulated Typology and a Comparative Multi-Level Analysis of the German and UK Low-Carbon Electricity Transitions (1990–2014). *Research Policy*, 45 (4), pp. 896–913. https://doi.org/10.1016/j.respol.2016.01.015.

Gillard, R., Gouldson, A., Paavola, J. and van Alstine, J. (2016). Transformational Responses to Climate Change: Beyond a Systems Perspective of Social Change in Mitigation and Adaptation. *Wiley Interdisciplinary Reviews: Climate Change*, 7 (2), pp. 251–265. https://doi.org/10.1002/wcc.384.

Gillespie, S., Poole, N., van den Bold, M., Bhavanic, R. V., Dangourd, A. A. and Shettye, P. (2019). Leveraging Agriculture for Nutrition in South Asia: What Do We Know, and What Have We Learned? *Food Policy*, 82 (January), pp. 3–12.

Glover, D. and Poole, N. (2019). Principles of Innovation to Build Nutrition-Sensitive Food Systems in South Asia. *Food Policy*, 82 (January), pp. 63–73.

Grin, J., Rotmans, J., and Schot, J. (2010). *Transitions to Sustainable Development: New Directions in the Study of Long Term Transformative Change*. Routledge, New York.

Grubinger, V., Berlin, L., Berman, E., Fukagawa, N., Kolodinsky, J. Neher, D., Parsons, B., et al. (2010). *Food Systems*. Transdisciplinary Research Initiative (TRI), Spire of Excellence Proposal. University of Vermont, Burlington.

Hall, A. (2009). Challenges to Strengthening Agricultural Innovation Systems: Where Do We Go from Here? In Scoones, I., Chambers, R. and Thompsons, J., eds., *Farmer First Revisited: Farmer-Led Innovation for Agricultural Research and Development*. Practical Action, Rugby, UK.

Hall, A. (2012). Partnerships in Agricultural Innovation: Who Puts Them Together and Are They Enough? In *Improving Agricultural Knowledge and Innovation Systems*. OECD Conference Proceedings. Organisation for Economic Co-operation and Development (OECD), Paris.

Hall, A., Dijkman, J., Taylor, B., Williams, L. and Kelly, J. (2016). Synopsis: Towards a Framework for Unlocking Transformative Agricultural Innovation. Discussion Paper 1. Commonwealth Scientific and Industrial Research Organisation (CSIRO), Canberra.

Hays, R. and Hall, A. (2019a). Sundrop Farms, Australia. In Kelly, J., ed., *Public Agricultural Research and Development in an Era of Transformation: The Challenge of Agri-Food System Innovation*. Resource Document I: Case Studies. CGIAR Independent Science and Partnership Council (ISPC) Secretariat and Commonwealth Scientific and Industrial Research Organisation (CSIRO), Rome and Canberra.

Hays, R. and Hall, A. (2019b). Australian Cotton Industry. In Kelly, J., ed., *Public Agricultural Research and Development in an Era of Transformation: The Challenge of Agri-Food System Innovation*. Resource Document I: Case Studies. CGIAR Independent Science and Partnership Council (ISPC) Secretariat and Commonwealth Scientific and Industrial Research Organisation (CSIRO), Rome and Canberra.

Hays, R. and Hall, A. (2019c). Golden Rice. In Kelly, J., ed., *Public Agricultural Research and Development in an Era of Transformation: The Challenge of Agri-Food System Innovation*. Resource Document I: Case Studies. CGIAR Independent Science and Partnership Council (ISPC) Secretariat and Commonwealth Scientific and Industrial Research Organisation (CSIRO), Rome and Canberra.

Hays, R. and Hall, A. (2019d). BARLEYmaxTM. In Kelly, J., ed., *Public Agricultural Research and Development in an Era of Transformation: The Challenge of Agri-Food System Innovation*. Resource Document I: Case Studies. CGIAR Independent Science and Partnership Council (ISPC) Secretariat and Commonwealth Scientific and Industrial Research Organisation (CSIRO), Rome and Canberra.

Hays, R. and Hall, A. (2019e). Novacq™. In Kelly, J., ed., *Public Agricultural Research and Development in an Era of Transformation: The Challenge of Agri-Food System Innovation*. Resource Document I: Case Studies. CGIAR Independent Science and Partnership Council (ISPC) Secretariat and Commonwealth Scientific and Industrial Research Organisation (CSIRO), Rome and Canberra.

Hays, R., Hall, A. and Dijkman, J. (2019). Salmon Production in Chile. In Kelly, J., ed., *Public Agricultural Research and Development in an Era of Transformation: The Challenge of Agri-Food System Innovation*. Resource Document I: Case Studies. CGIAR Independent Science and Partnership Council (ISPC) Secretariat and Commonwealth Scientific and Industrial Research Organisation (CSIRO), Rome and Canberra.

Hekkert, M., Suurs, R. A. A., Negro, S., Kuhlmann, S. and Smits, R. (2007). Functions of Innovation Systems: A New Approach for Analysing Technological Change. *Technological Forecasting and Social Change*, 74 (4), pp. 413–432.

Herrero, M., Mason-D'Croz, D., Palmer, J., Benton, T. G, Bodirsky, B. L., Bogard, J., Hall, A., et al. . Future Technologies and Food-Systems Innovation for Accelerating Progress towards the Sustainable Development Goals. In preparation.

Hughes, T. P. (1987). The Evolution of Large Technological Systems. In Bijker, W., Hughes, T. P. and Pinch, T., eds., *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*. MIT Press, Cambridge, MA.

IPES (International Panel of Experts on Sustainable Food Systems). (2015). *The New Science of Sustainable Food Systems: Overcoming Barriers to Food Systems Reform*. Brussels.

IPES-Food. (2017). *Too Big to Feed: Exploring the Impacts of Mega-Mergers, Consolidation, and Concentration of Power in the Agri-Food Sector*. Brussels.

ISPC (CGIAR Independent Science and Partnership Council). (2015). *Strategic Study of Good Practice in AR4D Partnership*. Rome.

Kahn, M. E. (2014). *Sustainable and Smart Cities*. Policy Research Working Paper 6878. Washington, DC: World Bank.

Kauffman, S. (1995). *At Home in the Universe: The Search for Laws of Self-Organization and Complexity*. Oxford University Press, Oxford, UK.

Kemp, R., Parto, S. and Gibson, R. B. (2005). Governance for Sustainable Development: Moving from Theory to Practice. *International Journal of Sustainable Development*, 8 (1/2), pp. 12–30.

Kemp, R., Schot, J. and Hoogma, R. (1998). Regime Shifts to Sustainability through Processes of Niche Formation: The Approach of Strategic Niche Management. Technology Analysis and Strategic Management, 10 (2), pp. 175–198. https://doi.org/10.1080/09537329808524310.

Kern, F. and Markard, J. (2016). Analysing Energy Transitions: Combining Insights from Transition Studies and International Political Economy. In Van de Graaf , T., Sovacool, B., Ghosh, A., Kern, F. and Klare, M., eds., *The Palgrave Handbook of the International Political Economy of Energy*. Palgrave Macmillan, London.

Klitkou, A., Bolwig, S., Hansen, T. and Wessberg, N. (2015). The Role of Lock-in Mechanisms in Transition Processes: The Case of Energy for Road Transport. *Environmental Innovation and Societal Transitions*, 16 (September), pp. 22–37. https://doi.org/10.1016/j.eist.2015.07.005.

Kurtz, C. F. and Snowden, D. J. (2003). The New Dynamics of Strategy: Sense-Making in a Complex and Complicated World. *IBM Systems Journal*, 42 (3), pp. 462–483.

Lachman, D. A. (2013). A Survey and Review of Approaches to Study Transitions. *Energy Policy*, 58 (C), pp. 269–276. https://doi.org/10.1016/j.enpol.2013.03.013.

Lam, J. C. K., Walker, R. M. and Hills, P. (2014). Interdisciplinarity in Sustainability Studies: A Review. *Sustainable Development*, 22 (3), pp. 158–176. https://doi.org/10.1002/sd.533.

Lidder, P. and Dijkman, J. (2019). Orange-Fleshed Sweet Potato in Sub-Saharan Africa. In Kelly, J., ed., P*ublic Agricultural Research and Development in an Era of Transformation: The Challenge of Agri-Food System Innovation*. Resource Document I: Case Studies. CGIAR Independent Science and Partnership Council (ISPC) Secretariat and Commonwealth Scientific and Industrial Research Organisation (CSIRO), Rome and Canberra.

Loorbach, D. (2010). Transition Management for Sustainable Development: A Prescriptive, Complexity-Based *Governance Framework. Governance, An International Journal of Policy, Administration, and Institutions*, 23 (1), pp. 161–83. https://doi.org/10.1111/j.1468-0491.2009.01471.x.

Lundvall, B. A. (1992). *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. Pinter, London.

Markard, J. and Truffer, B. (2008). Technological Innovation Systems and the Multi-Level Perspective: Towards an Integrated Framework. *Research Policy*, 37 (4), pp. 596–615.

Markard, J., Raven, R. and Truffer, B. (2012). Sustainability Transitions: An Emerging Field of Research and Its Prospects. *Research Policy*, 41 (6), pp. 955–967. https://doi.org/10.1016/j.respol.2012.02.013.

Mazzucato, M. (2015). *The Entrepreneurial State. US edition*. Public Affairs, New York.

Meadowcroft, J. (2011). Engaging with the Politics of Sustainability Transitions. *Environmental Innovation and Societal Transitions*, 1 (1), pp. 70–75. https://doi.org/10.1016/j.eist.2011.02.003.

Mersmann, F., Holm Olsen, K., Wehnert, T. and Boodoo, Z. (2014). *From Theory to Practice: Understanding Transformational Change in NAMAs*. UNEP DTU Partnership (UN Environment and Technical University of Denmark), Copenhagen.

Meynard, J.-M., Jeuffroy, M.-H., Le Bail, M., Lefèvre, A., Magrini, M.-B. and Michon, C. (2017). Designing Coupled Innovations for the Sustainability Transition of Agrifood Systems. *Agricultural Systems*, 157 (C), pp. 330–339.

Monke, J. (2016). Agricultural Research: Background and Issues. Congressional Research Service 7-5700. Washington, DC.

Mytelka, L. K. (2003). *New Wave Technologies: Their Emergence, Diffusion and Impact: The Case of Hydrogen Fuel Cell Technology and the Developing World*. UNU-INTECH Discussion Paper Series 3. United Nations University, Helsinki.

Nelson, R. R. (1988). National Systems of Innovation: Preface to Part V. In Dosi, G., Freeman, C. Nelson, R., Silverberg, G. and Soete, L., eds., *Technical Change and Economic Theory*. Pinter, London.

Nelson, R. R. and Winter, S. G. (1977). In Search of a Useful Theory of Innovation. In Stroetmann, K. A., ed,. *Innovation, Economic Change and Technology Policies*. Interdisciplinary Systems Research (Analysis — Modeling — Simulation). Birkhäuser, Basel.

Nordic Council of Ministers. 2017. *Nordic Bioeconomy: 25 Cases for Sustainable Change*. Copenhagen.

OECD (Organisation for Economic Co-operation and Development). (2011). *Fostering Innovation to Address Social Challenges*. Workshop Proceedings. OECD Innovation Strategy. Paris.

OECD. (2015). *System Innovation: Synthesis Report*. Paris. https://www.innovationpolicyplatform.org/sites/default/files/general/SYSTEMINNOVATION_FINALREPORT_0.pdf.

Patterson, J., Schulz, K., Vervoort, J., van der Hel, S., Widerberg, O., Adler, C., Hurlbert, M., Anderton, K., Sethi, M., and Barau, A. (2017). Exploring the Governance and Politics of Transformations towards Sustainability. *Environmental Innovation and Societal Transitions* 24 (24): 1–16. https://doi.org/10.1016/j.eist.2016.09.001.

PBS. (2009). Timeline: History of the Electric Car. NOW on PBS, week of October 30, 2009. http://www.pbs.org/now/shows/223/electric-car-timeline.html.

Pedersen, B. G. (2015). Wind of Change: Transformational Change through Wind Power in Danish Electricity Production: Moving towards 100% Renewable Energy. In Olsen, K. H. and Fenhann, J., eds., *Transformational Change for Low Carbon and Sustainable Development*. UNEP DTU Partnership (UN Environment and Technical University of Denmark), Copenhagen.

Perry, B. D. and Dijkman, J. (2019). East Coast Fever Infection and Treatment Method. In Kelly, J., ed., *Public Agricultural Research and Development in an Era of Transformation: The Challenge of Agri-Food System Innovation*. Resource Document I: Case Studies. CGIAR Independent Science and Partnership Council (ISPC) Secretariat and Commonwealth Scientific and Industrial Research Organisation (CSIRO), Rome and Canberra.

Perry, B. D., Dijkman, J. and Benigno, C. (2019). Foot and Mouth Disease Eradication in the Philippines. In Kelly, J., ed., *Public Agricultural Research and Development in an Era of Transformation: The Challenge of Agri-Food System Innovation*. Resource Document I: Case Studies. CGIAR Independent Science and Partnership Council (ISPC) Secretariat and Commonwealth Scientific and Industrial Research Organisation (CSIRO), Rome and Canberra.

Reardon, T., Echeverria, R. G., Berdegué, J. A., Minten, B., Liverpool-Tasie, L. S., Tschirley, D. and Zilberman, D. (2018). Rapid Transformation of Food Systems in Developing Regions: Highlighting the Role of Agricultural Research and Innovations. *Agricultural Systems*, 172. Article in press. https://doi.org/10.1016/j.agsy.2018.01.022.

Reardon, T., Lu, L. and Zilberman, D. (2017). Links among Innovation, Food System Transformation, and Technology Adoption, with Implications for Food Policy: Overview of a Special Issue. *Food Policy*, 83 (February), pp. 285–288. http://dx.doi.org/10.1016/j.foodpol.2017.10.003.

Reynolds, T., Anderson, C. L., Biscaye, P. and Fowle, M. (2017). *Funding for Agricultural Research and Development Public Goods*. EPAR Technical Report #329. Evans School Policy Analysis and Research Group (EPAR), University of Washington, Seattle.

Rip, A. and Kemp, R. (1998). Technological Change. In Rayner, S. and Malone, E. L., eds., *Human Choice and Climate Change*. Batelle Press, Columbus, Ohio.

Rosenfield, P. L. (1992). The Potential of Transdisciplinary Research for Sustaining and Extending Linkages between the Health and Social Sciences. *Social Science and Medicine* 35 (11), pp. 1343–1357.

Rotmans, J., Kemp, R. and van Asselt, M. (2001). More Evolution than Revolution: Transition Management in Public Policy. *Foresight*, 3 (1), pp. 15–31.

Rotmans, J. and Loorbach, D. (2009). Complexity and Transition Management. *Journal of Industrial Ecology*, 13 (2), pp. 184–196. https://doi.org/10.1111/j.1530-9290.2009.00116.x.

Rotmans, J., Loorbach, D. A. and Kemp, R. (2007). *Transition Management: Its Origin, Evolution, Critique*. Dutch Research Institute for Transitions, Rotterdam. http://hdl.handle.net/1765/37240.

Schot, J. and Steinmueller, W. E. (2016). Framing Innovation Policy for Transformative Change: Innovation Policy 3.0. Draft Version 2, updated 18 October 2016. Science Policy Research Unit (SPRU), University of Sussex, Brighton, UK.

Shamsi, H. A., Almutairi, A. G. and Mashrafi, S. A. (2018). Food and Nutrition Systems in India Change as a Result of the Nutrition Transition: The Implications on the Food and Nutrition System in Relating to Changes in the Food Supply and Dietary Intakes. *Global Journal of Health Science*, 10 (9), pp. 74–80. https://doi.org/10.5539/gjhs.v10n9p74.

Smith, A., Stirling, A. and Berkhout, F. (2005). The Governance of Sustainable Socio-Technical Transitions. *Research Policy*, 34 (10), pp. 1491–1510.

Smith, A., Voßb, J.-P. and Grin, J. (2010). Innovation Studies and Sustainability Transitions: The Allure of the Multi-Level Perspective and Its Challenges. *Research Policy*, 39 (4), pp. 435–448.

Stephan, P. (2015). *How Economics Shapes Science*. Harvard University Press, Cambridge, MA.

Stirling, A. (2008). "Opening Up" and "Closing Down" Power, Participation, and Pluralism in the Social Appraisal of Technology. *Science, Technology, and Human Values*, 33 (2), pp. 262–294.

Stirling, A., Leach, M., Mehta, L., Scoones, I., Smith, A., Stagl, S. and Thompson, J. (2007). *Empowering Designs: Towards More Progressive Appraisal of Sustainability*. STEPS Working Paper 3. STEPS Centre, Brighton, UK.

Stirling, A., O'Donovan, C. and Ayre, B. (2018). Which Way? Who Says? Why? Questions on the Multiple Directions of Social Progress. *Technology's Stories*, May 24. Society for the History of Technology,

Swinburn, B. A., Kraak, V. I., Allender, S., Atkins, V. J., Baker, P. I., Bogard, J. R., Brinsden, H., et al. (2019). The Global Syndemic of Obesity, Undernutrition, and Climate Change: The Lancet Commission Report. *The Lancet*, 393 (10173), pp. 791–846.

Taylor, B. M. (2019a). Environmental Management, Cotton Industry, Australia. In Kelly, J., ed., *Public Agricultural Research and Development in an Era of Transformation: The Challenge of Agri-Food System Innovation*. Resource Document I: Case Studies. CGIAR Independent Science and Partnership Council (ISPC) Secretariat and Commonwealth Scientific and Industrial Research Organisation (CSIRO), Rome and Canberra.

Taylor, B. M. (2019b). Rural Water Use Efficiency, Queensland. In Kelly, J., ed., *Public Agricultural Research and Development in an Era of Transformation: The Challenge of Agri-Food System Innovation*. Resource Document I: Case Studies. CGIAR Independent Science and Partnership Council (ISPC) Secretariat and Commonwealth Scientific and Industrial Research Organisation (CSIRO), Rome and Canberra.

Thompson, J., Millstone, E., Scoones, I., Ely, A., Marshall, F., Shah, E. and Stagl, S. (2007). *Agri-Food System Dynamics: Pathways to Sustainability in an Era of Uncertainty*. STEPS Working Paper 4. STEPS Centre, Brighton, UK.

Thompson, J. and Scoones, I. (2009). Addressing the Dynamics of Agri-Food Systems: An Emerging Agenda for Social Science Research. *Environmental Science and Policy*, 12 (4), pp. 386–397.

Unruh, G. C. (2000). Understanding Carbon Lock-in. *Energy Policy*, 28 (12), pp. 817–830.

Unruh, G.C. (2002). Escaping Carbon Lock-In. *Energy Policy*, 30 (4), pp. 317–325. https://ac-els-cdn-com.virtual.anu.edu.au/.

van den Bergh, J. C. J. M. (2011). *Environmental and Climate Innovation: Limitations, Prices and Policies*. Papers on Economics and Evolution #1023. Max Planck Institute of Economics, Jena, Germany.

van den Bergh, J. C. J. M., Truffer, B. and Kallis, G. (2011). Environmental Innovation and Societal Transitions: Introduction and Overview. *Environmental Innovation and Societal Transitions*, 1 (1), pp. 1–23. https://doi.org/10.1016/j.eist.2011.04.010.

von Schomberg, R. (2011). Prospects for Technology Assessment in a Framework of Responsible Research and Innovation. In *Technikfolgen abschätzen lehren: Bildungspotenziale transdisziplinärer Methode*. Springer VS, Wiesbaden, Germany.

Walker, B., Holling, C. S., Carpenter, S. R. and Kinzig, A. (2004). Resilience, Adaptability and Transformability in Social-Ecological Systems. *Ecology and Society*, 9 (2): 5. http://www.ecologyandsociety.org/vol9/iss2/art5/.

Wikipedia. (2019). History of the Electric Vehicle. Last edited March 16, 2019. http://en.wikipedia.org/wiki/History_of_the_electric_vehicle.

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., et al. (2019). Food in the Anthropocene: The EAT–Lancet Commission on Healthy Diets from Sustainable Food Systems. *The Lancet*, 393 (10170), pp. 447–492.

Williams, L. (2019). Mass Marketing of the Treadle Pump in Bangladesh. In Kelly, J., ed., *Public Agricultural Research and Development in an Era of Transformation: The Challenge of Agri-Food System Innovation*. Resource Document I: Case Studies. CGIAR Independent Science and Partnership Council (ISPC) Secretariat and Commonwealth Scientific and Industrial Research Organisation (CSIRO), Rome and Canberra.

World Bank. (2006). *Enhancing Agricultural Innovation: How to Go beyond the Strengthening of Research Systems*. Washington, DC. https://openknowledge.worldbank.org/handle/10986/24105.

World Bank. (2012). *Agricultural Innovation Systems: An Investment Sourcebook*. Washington, DC.

World Bank. (2017a). *Turn Down the Heat: Why a 4°C Warmer World Must Be Avoided*. Washington, DC.

World Bank. (2017b). *Enabling the Business of Agriculture 2017*. Washington, DC. http://documents.worldbank.org/curated/en/369051490124575049/Enabling-the-business-of-agriculture-2017.

WEF (World Economic Forum). (2018). *Annual Report 2017–2018*. Geneva.

WRI (World Resources Institute). (2018). *Creating a Sustainable Food Future: A Menu of Solutions to Feed Nearly 10 Billion People by 2050*. World Resources Report. Washington, DC. https://www.wri.org/publication/creating-sustainable-food-future.

ANNEX 1.
CASE STUDY TEMPLATE

PREAMBLE

CSIRO and the Secretariat of the Independent Science and Partnership Council of the CGIAR are collaborating to investigate the nature of agri-food system innovation pathways and to explore how transformational innovation pathways can be enabled. Part of this work involves the development of a data base of case studies. The purpose of these studies is to develop a multi-dimensional account of innovation that reveals the scope of change processes at play, how these unfold over time, and their relationship to the scale and nature of impact achieved. Elements of this narrative may include

- Initiating events and key turning points during the innovation process;
- The role of research and technology in the wider process of change;
- The range of players involved in the innovation process and their changing roles over time;
- Alliances and partnerships that were pivotal in the innovation process;
- Institutional arrangements (markets, states, corporate hierarchies, networks, associations, communities, etc.) and the certification, regulatory, pricing and other policy measures that have formed part of the innovation;
- The nature of the innovation process, such as the commercialization of a (public) research technology by the private sector; the public policy, regulatory regimes, or governance arrangements that stimulated or facilitated technological and practice changes; or market disruptions arising from new business models and or changing societal demands and values; and
- Evidence from independent or objective evaluations and impact assessments about the current and future scale and nature of impacts

ANNOTATED CASE STUDY TEMPLATE:

SUMMARY

This section highlights the key points to alert readers about what to expect in the case study: the nature of the innovation being discussed, the key processes at play and the headline impacts.

CHALLENGE/OPPORTUNITY

This section outlines the problem that the innovation discussed is providing a solution to and/or the scope of the opportunity that the innovation discussed is unlocking.

INNOVATION

This section provides a brief description of the change that has taken place to create social, economic and/or environmental value. For example:

- the introduction and spread of a nutritionally enhanced food product in the market;

- the development of a public-private sector research and development consortium that that supplies farmers with seeds adapted to changing environmental and market conditions;
- the development of a policy regime that provides incentives to multiple stakeholders to collaborate in the development and implementation of environmentally sensitive technologies and practices;
- Participatory technology development with farmers and the subsequent spread of new farming practices; and
- The public or private promotion of a new technology and the cluster of policy and price incentives and regime changes that enabled the use and spread of the technology.

This section may need to give a brief description of the technological dimension of the innovation (for example, the development of new seed varieties), but it should also describe the allied institutional, market and policy change dimensions that have been involved in the deployment and use of the technology.

Note that the description of a technological breakthrough or research finding does not constitute an innovation: innovation is the application and use of technology, knowledge and ideas for social, economic and/or environmental benefit

INNOVATION PATHWAY

This section is the core of the case study. Its purpose is to describe in detail the chain of events, players and processes in the innovation process. A time line of key events should be presented. It maybe useful to break the narrative down into different phases that may be punctuated by key events or turning points. These phases can then be used to explain the role of players, partners and alliances and the way these contributed to creating the opportunities and conditions for the innovation to take place. The narrative should not be purely about research and technology or the findings of different research projects. However, it is useful to describe the role of research in different phases, if appropriate. Early phases may consist of initiating or foundational activities. They may also involve technological breakthroughs produced by research (although they do not always involve such breakthroughs). Later phases might involve the expansion of pilots or the spread of the innovation through the market or farming communities. The narrative should also describe any challenges or dead ends that were encountered along the way, particularly if the realization of these limitations led to new directions or approaches.

IMPACT EVIDENCE

This section provides quantified independent or objective evidence of impact from evaluations and impact studies with the source of impact data or impact estimates cited. This material should document impact that has actually occurred or been established to date. Impact projections can also be presented, but these need to be accompanied by the assumptions made and the theory of change that underpins these assumptions.

CONSEQUENCES

This section seeks to document the consequences or follow-on effects from the innovation described. For example, new partnerships or capabilities developed during the innovation might have been used to tackle other challenges. The introduction of a new food product might have led to the development of a new market segment, stimulating private investment and innovation to serve this new market. Transformation of markets, societal values and attendant polices might have created the conditions for the development of new technology or the deployment of existing technology through both incremental and radical modes of innovation.

PATTERNS OF INNOVATION AND IMPACT PROCESSES TABLE

This table captures the key innovation and impact process features of the case study. Entries to the table need to be brief and supported by the narrative of the case study. It can also be used as a checklist when writing the case study to make sure that the main themes have been covered in the narrative.

Initiator	
Critical features	
Role of research	
Operational alliances	
Strategic alignment of stakeholders at sector or national level	
Solution, product or system innovation	
Scope of impact (and metrics)	

REFERENCES AND FURTHER READING

Independent Science and Partnership Council

CGIAR Independent Science & Partnership Council (ISPC) Secretariat
c/o FAO, Viale delle Terme di Caracalla 00153 Rome, Italy
t: +39 06 570 52103
http://ispc.cgiar.org