RACE for 2030

RELIABLE AFFORDABLE CLEAN ENERGY

B1 Research Project

Food Value Chain

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Food Value Chain: Supporting Australia's food value chains to transform their energy productivity

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Acknowledgement of Country

The authors of this report would like to respectfully acknowledge the Traditional Owners of the ancestral lands throughout Australia and their connection to land, sea and community. We recognise their continuing connection to the land, waters, and culture and pay our respects to them, their cultures and to their Elders past, present, and emerging.

What is RACE for 2030?

RACE for 2030 CRC is a 10-year cooperative research centre with AUD350 million of resources to fund research towards a reliable, affordable, and clean energy future. racefor2030.com.au

Disclaimer

Executive Summary

The food value chain faces many challenges as it delivers essential and valued services to consumers while confronting climate change, increasing costs, disruptive innovation, extreme competition and many other issues. This project explored ways that energy productivity improvement could address these challenges directly by saving energy and indirectly by delivering multiple business benefits (including improvements in technical and business operations as well as practices which ultimately would reduce waste), especially through collaborative action across the value chain.

Through research and consultation with industry, existing activity, understanding and attitudes to energy productivity and potential for collaborative action across the food value chain were clarified. Options for models to mobilise collaborative action where developed and feedback sought. This led to recommendations for a consortium-based approach to build awareness and drive action.

The project applied three core elements:

- Focus on energy productivity, not just energy efficiency: energy productivity focuses on energy-related actions that add business value (in ways that may not immediately seem to be related to energy) for each unit of energy consumed.
- Focus on value chains which consider inputs, supply chain participants and end-consumers, and their shared interests and interdependencies.
- Application of a Systems Innovation Research model that reflects the complexities and interrelationships between elements involved in driving change, highlighting interdependencies, exchanges and flows between value chain participants to provide a new means for optimising systems level benefits.

Research

Three streams of desktop research were pursued.

One stream explored the nature of the food value chains, including the relationships, financial flows, environmental impacts, organisations and how these could contribute to framing a value chain model that emphasises the interdependence of participants on each other, and on spending by end-consumers based on their perceptions of value.

A second stream reviewed major emerging drivers such as reduction of energy costs, regulations, customer demand that are increasing the importance and potential value of more collaborative activity, particularly on energy productivity, across the food value chain.

The third stream reviewed energy-related measures, technologies and activities that could be applied within and across the food value chain and the range of potential business benefits they could provide. Digitalisation within firms and across the value chain were recognised as important enablers of energy productivity.

These streams of research fed into the action research and application of the Systems Innovation Research model to identify key issues and to develop possible pathways based on realistic assessments of knowledge, attitudes, market structures, etc.

Consultation

Review of literature on the priorities and activities across the food value chain led to recognition of the status of energy productivity among industry and researchers. Once the desktop research was complete, key stakeholders identified in the food value chain were engaged and a series of individual interviews with participants in the food value chain and researchers were undertaken. Messages from these interviews were integrated with insights from the research and application of the systems innovation approach. These were tested with a focus group comprised of some of the interviewees to confirm that they reflected the various opinions of group. The outcomes were incorporated into recommendations for further action.

Key Messages

Priorities varied across food value chain stakeholders, but included reducing food waste, packaging, increasing renewable energy, the climate impacts of refrigerants and cost/profit issues.

Substantial research, development and innovation is occurring. However, most of it is at the individual business or industry level. Some groups, such as Food Innovation Australia Limited (FIAL) and Fight Food Waste (FFW) Cooperative Research Centre (CRC), are working more broadly with life cycle assessment, supply chain projects, etc. Most of the focus is on food waste or process-specific areas in an individual business.

Emerging issues with potential to justify more attention on energy productivity and collaboration that were identified included:

- **Increasingly ambitious decarbonisation commitments and obligations.** For larger businesses, there is increasing focus on Scope 3 emissions (emissions a business influences but doesn't control – mainly associated with inputs and emissions generated by customers): this increases pressure to collaborate. Much of the focus is on methane from food production and waste, and the global warming impacts of refrigerants which has serious implications for costs and performance of refrigeration. Renewable energy and carbon offsets were mentioned as potential options.
- **Circular economy industrial models.** The principle that 'there should be no such thing as waste' underpins CE. Minimising waste and finding ways to transform waste into useful product or potentially valuable resources that markets will consume make collaboration and development of new business models more important.
- **Digitalisation and connection.** Real time, meaningful knowledge supports optimal action. Applying it across businesses helps to identify 'frictions', inefficiencies and contradictions between key performance indicators (KPIs) and perceptions of what is important.
- **Consumer, investor and government focus on environmental performance is increasing.** Not all participants saw strong signals such as financial incentives or consumers prepared to pay for change.
- Potential to partner with, build on or complement existing work by applying an 'energy productivity lens' and building greater awareness of how it can help them to achieve their existing and additional objectives.

Interviewees highlighted challenges in finding resources to pursue energy productivity. For example, profit margins are tight, some companies have significant market power, some 'free-ride' on efforts of others, contractual requirements and business models can impede innovation, SMEs may lack capacity to change, customers often will not pay more for higher value, many input costs are outside a firm's control, and regulatory factors can complicate change.

Energy productivity messages

Energy efficiency and productivity were seen as important, but not important enough to be a high priority although there was support for a combination of industry leadership and government support for development of collaborative energy productivity improvement. We found limited understanding of the potential benefits of energy-related action beyond reducing energy costs.

Factors that undermined prioritisation of energy productivity included:

- Framing that focused just on reducing energy costs of an individual business. As noted earlier, energy productivity aims to enhance business value through capturing multiple benefits, so it is potentially worth far more than just energy savings and benefits may be shared across multiple businesses.
- The energy dimensions of many decisions were often not recognised during key decision-making processes. For example, management of refrigerants and capital costs of transition to low climate impact refrigerants are enmeshed in energy factors including impacts on energy efficiency and cooling capacity, capital and operating costs, food quality and waste.
- The cost (and climate impact) of energy use by each participant flows through to the rest of the value chain, but is hidden in the overall price paid for the input at each interface. The final retail price of food includes the cumulative cost of all the energy used in the value chain.
- On one hand reliable energy (and production) are important for all value chain participants but for many, direct energy costs are a small proportion of total costs. Making changes to energy systems may be seen as a risk to production. Poor communication across silos within businesses can also impede consideration and funding of energy productivity measures.
- Some industry participants suggested that it would be helpful if carbon offsets created by food industry businesses could be sold to others within the food value chain to build a positive shared narrative on climate. There is underutilised potential to create energy-related Australian Carbon Credit Units.

Value chain messages

Most businesses focus on immediate suppliers, the business itself, and immediate customers: this is the traditional business model. For complex and long value chains with many participants of widely varying size and market power, this allows many inefficiencies to occur.

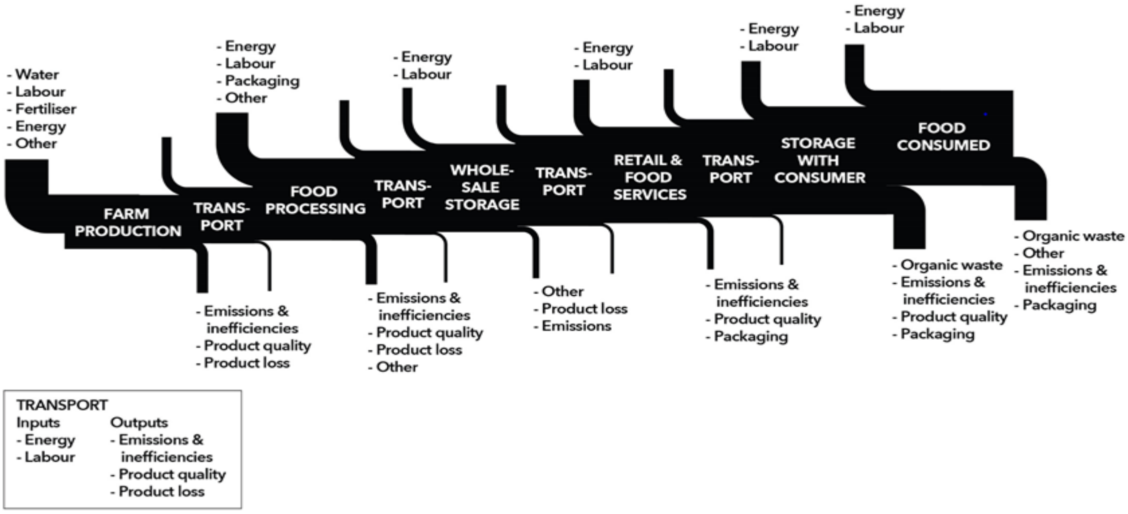


Figure 1. Flow diagram that highlights the potential for value add or loss at each stage of the value chain, and the progressive increase in value of product.

Project participants flagged a number of potentially significant areas where collaboration across some or all of the value chain is potentially important, such as standardisation and security of data and data systems, streamlining and updating of regulatory frameworks, identification and implementation of training.

Systems Innovation Research model messages

Systems change happens when multiple, interconnected elements — technology, people, culture, markets, policies and environments — reorient and adjust in a non-linear way, to allow for emergent solutions and new ways of working to scale and diffusion. Tipping points can be created when complex adaptative systems cross critical thresholds. Sensitive interventions that create 'kicks' or 'shifts' in a system can deliver rapid impact[1].

The Systems Innovation model used in this project is illustrated in Figure 2. It shows the complexity of real-world change and innovation that must be managed for success. This makes it clear that appropriate resource allocation and collaboration across the food value chain will be fundamental to future success in driving energy productivity improvement in the food value chain.

As part of the project, barriers and opportunities identified by participant interviews and/or by the research team were mapped on this framework to support development of a path forward.

Figure 2. Levers of change (Deep Demonstrations - Climate-KIC, 2023)

[1] Farmer, J.D., Hepburn, C., Ives, M.C., Hale, T., Wetzer, T., Mealy, P., Rafaty, R., Srivastav, S. and Way, R., 2019. Sensitive intervention points in the post-carbon transition. *Science*, *364*(6436), pp.132-134.

Where to from here?

During the project it became clear that a lot of valuable research, innovation and delivery regarding energy related issues was occurring – but it was not perceived to be related to energy productivity improvement. This means there is substantial potential to drive energy productivity improvement by working with and building on existing organisations and activities. The challenge is to integrate energy productivity into existing activity and expand its scope. This will not happen without provision of financial and human resources to supplement existing capacity in groups like Fight Food Waste (FFW), Food Innovation Australia Limited (FIAL), Agrifutures, universities, etc, and practical demonstrations of how energy productivity action can deliver multiple benefits that food industry businesses value.

On this basis, the project team recommends creation of a Consortium to lead the transformation. This will require RACE for 2030, Government and Industry funding for establishment. An aim of this group would be to lead/consolidate/evolve the areas of focus in a cascade strategy and set a roadmap to enable continuous systems innovations required for enabling energy productivity gains. The framework for the consortium is shown in Figure 3.

Vision

Energy productivity (EP) gains deliver multi-benefits through systems innovation capabilities and cross-cutting policy mechanisms to leverage procedures and technologies to decarbonize food value chains and capture business value.

Values

EP enabled systems innovation secures food sovereignty	Responsible food production and consumption enabled through EP gains	EP gains have multi-benefits in sustainable food production and consumption systems

Focus areas

Set policy framework for cross-cutting systems levers that enable competitiveness, avoid price volatility, and reduce emissions while removing barriers and market distortions	Identification of demand-side mechanisms that will expedite kicks and shifts in energy productivity improvements	Capability development for leading systems innovation through supporting infrastructures, technologies and new business models – co-designing and testing prototypes to generate data on sustainability and multi-benefit indicators

Objective/s

1. Build motivated consortium to champion energy productivity gains as an enabler of decarbonization by developing capabilities and showcasing best practice
2. Demonstrate and communicate the narrative about the high value opportunities for energy productivity gains across food production and consumption systems that create shared value and enhance energy performance
3. Identify and track the multi-benefits gained across the value chain through implementation of technology and process related improvements for energy performance
4. Account for GHG reductions in energy productivity gains across a value chain as part of National Determined Contribution – net zero by 2050 and reduce Greenhouse gas emissions by 43% from 2005 levels
5. Evidence multi-benefit metrics for basis of innovative funding mechanisms to scale growth of energy productivity solutions

Key Projects

1. Establish Consortium and engagement mechanism with cross value chain participation
2. Take a systems innovation approach and coordinate of portfolio of actions levers of change, linking to existing work where possible
3. Adopt a continuous capability development and learning approach across Consortium memberships and develop specific EP toolkit and training for enabling capability development.

Measures of Success

Motivated group established who are overseeing implementation of EP gain projects supported by coordinated systems innovation.
Levers identified that best enable multiple systems benefits in form of emissions reductions, financial and nature positive benefits and livelihoods and wellbeing for value chain participants
Embed and raise profile of EP multi-benefit indicators through partnerships with FFW and other alliances.

Figure 3. Energy Productivity Cascade strategy

Contents

1 Background and context

The global food sector is responsible for about 30% of energy consumption and it is the largest user of land on the planet, with vineyards alone occupying about 7.5 million hectares of land, and cereals cultivated across 700 million hectares of land (Jagtap et al., 2019).

Energy enables most processes across the food value chain including growing, processing, packaging, distributing, storing, preparing, serving, and disposing. While energy can account for 15% of operational costs in a food and beverage manufacturing business (Australian Government-Food and Beverage, 2022), it may account for a smaller proportion of operating costs in other segments of the value chain such as retail, where labour and other costs dominate. However, energy costs may be over 7% of total costs across the value chain (Jutsen et al., 2017).

Given the relevance of energy use across all stages of the value chain, the application of an energy productivity lens in the food value chain is able to shift the focus beyond energy costs (Neusel and Hirzel, 2022; Sovacool et al., 2021) and reveal how energy efficiency measures can deliver multiple business benefits (Finman and Laitner, 2001; Worrell et al., 2003, Cagno et al., 2019). Indeed, the identification of opportunities to productively manage energy can improve technical and business operations as well as practices which ultimately would reduce waste. Such improvements often depend upon data and analysis associated with energy productivity improvement. Moreover, the increasing concerns about climate change and other environmental issues adds further justification for a greater focus on energy productivity within the food value chain.

Our research has shown that in Australia there is extensive research and development activity in the food value chain, focusing on innovation and reduction of environmental impacts in specific industries and management of food waste, in some cases extending to supply chain and lifecycle issues. Examples of this activity are included later in this report.

However, there has been limited focus on energy use in food value chains and the role of energy productivity improvements in enabling multiple benefits to be captured. So far, the focus has been mostly limited to narrow consideration of energy cost savings, and on energy use by end-consumers, without the adoption of an energy productivity lens. This project explored possible reasons for this situation and justifications for stronger focus on energy productivity issues, stimulating collaboration across sectors within the food value chain.

1.1 Project aim and approach

This study combines an energy productivity lens with a value chain and systems innovation framework to identify and build coordinated action on high value pathways for decarbonisation and energy productivity improvement. As discussed below, its focus was on consultation and engagement with participants in the food value chain and further desk research to better understand existing attitudes and activity, leading to proposals for future activity intended to increase cross-value chain focus on energy productivity.

The nexus between productivity and energy usage in the value chain was explored in previous studies by the Australian Alliance for Energy Productivity (Jutsen et al., 2017a; Jutsen et al., 2017b; Jutsen et al., 2018). It is highlighted thoroughly in the RACE for 2030 Cooperative Research Centre (RACE for 2030) opportunity assessment studies, further discussing the energy productivity perspective including the technology & market transformation (Denham et al., 2021; Trianni et al., 2022). Section 1.2 delves into the specifics of energy productivity with the focus at value chain and system thinking perspective.

These studies identified the food value chain as a key area where these factors could contribute to decarbonising the economy, enabling opportunities for circular economy and systems innovation.

Initially RACE for 2030 partnered with the Australian Alliance for Energy Productivity (A2EP), University of Technology Sydney (UTS) and Climate-KIC Australia to deliver a study intended to explore two value chains; 1) dairy and meat and 2) fruit and vegetables. The research team initially planned to investigate these two for the reasons summarised in the table below (Table 1).

Table 1. Food Value Chains elements initially proposed for focus

Sub Value Chain	Key elements for focus and main challenges
Meat (especially beef and lamb) and dairy	Key factors for selection: • Domination of agricultural financial flows • High energy use and revenues Main challenges • Difficulty in responding to climate change pressures • Waste reduction/management issues
Fruit and Vegetables	Key factors for selection: • Growth markets • Responsible for majority of food waste in food waste and consumer behaviour • Key contributors for healthy diets • Potential value adding opportunities through extraction from waste • Potential innovative high-value food products Main challenges • Key players in the value chain located in remote locations • Low industrialisation of key activities

Sources: Biene et al., 2021; Brodribb & McCann, 2020; Jutsen et al., 2017; Ladha-Sabur et al., 2019; Ivanovich et al., 2023; Preiss, 2022; AFGC, 2023; Sustainable Victoria, 2020; ABS, 2023

However, the focus of the project shifted to a broader exploration of energy productivity in the overarching food value chain system for several reasons:

- Analysis of consumer spending found that, while only about 30% of household spending on food related products was for clearly defined products in these categories, they were components of almost all categories of households' food related spending: see Figure A1.2 for a breakdown of household spending on food-related products and services.
- Few interviewees focused specifically on the elements originally targeted, as their activities included a variety of products and/or multiple elements of the value chain.
- It was difficult to find detailed information on the specific dairy, meat, fruit and vegetable chains, or on the nature of purchasing by institutions and food services businesses.

The research team conducted an action-research study (see method section 2) involving participants from across the food value chain that have an interest in delivering innovation and cooperation to drive energy productivity improvement and broad-based decarbonisation. Action research integrates theory and action into a process whereby the research participants (those who experience the focus of the study) explore the focal issues alongside the researchers (Coghlan and Brydon-Miller, 2014). Participants included a range of businesses, industry organisations, researchers and government agencies, following suggestions by Jorgenson & Stephens, 2022, on the relevance of involving and coordinating multiple stakeholders and elements of a system to allow for an effective energy system transformation.

An anticipated outcome of the research is to build the case and momentum for follow-on collaborative action, inspired by the research that preceded the establishment of the Materials and Embodied Carbon Leaders' Alliance (MECLA, 2023). MECLA emerged from more than one year of research and development, as a group which is actively collaborating to define and deliver action to reduce embodied carbon in building and construction materials.

1.2 Key concepts: Energy productivity, Value chains and System change approach

The frameworks and concepts in this study had not been previously combined and they were also unfamiliar to many participants. This section explains each concept and framework drawing on desk research conducted during this project.

1.2.1 Energy productivity – multiple business benefits not just energy efficiency

The energy productivity approach focuses on both the potential to capture additional business and societal value as well as saving energy. In the past, most business energy efficiency audits and projects have focused on direct, short term energy cost savings for individual businesses or industry sectors. By taking a broader approach to capturing the multiple benefits of energy productivity action across value chains, potential untapped value can be unlocked. In many cases, capturing this value involves collaboration across businesses.

Most analysis of energy supply and use focuses on *final energy*, the forms and amounts of energy measured at the meter or fuel pump. Energy productivity uses *primary energy*, the amount of 'raw' energy harvested to supply the final energy.

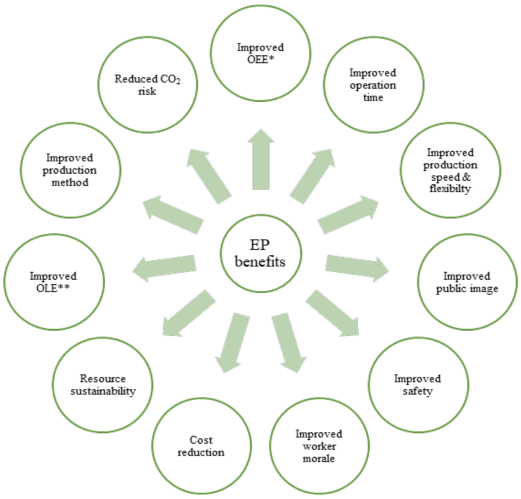
Interestingly, using primary energy as a metric instead of final energy places more emphasis on the use of a secondary energy source such as electricity rather than a primary fuel source such as e.g. natural gas or oil: in literature, many analyses focus on energy intensive activities consuming large amounts of primary fuels, such as manufacturing processes. However, the shift towards primary energy as a metric provides several key advantages for the purposes of this study: on the one hand it better correlates with total energy costs and carbon emissions; on the other hand, and more specifically for the food value chains, it increases the focus on electricity-intensive activities such as retailing and consumer energy use (Kanchiralla et al., 2021; Raggio et al., 2020).

In a nutshell, the energy productivity lens adopted in the study aims at incorporating the economic value of all factors affected by the change in energy use: for example, if an energy-efficient refrigerator also reduces food waste, capital costs and labour, the value of these factors would be counted as 'value added', as they would not have been captured without implementing the energy efficiency measure.

$$Energy\ productivity = \frac{Value\ added}{Unit\ of\ primary\ energy}$$

Focusing on the multiple benefits through a value-added approach is a significant shift from a narrow focus on cost savings. Several large-scale European projects have generated resources and tools to enable understanding and quantification of the multiple benefits of energy productivity improvement. For example, the Combi Project (COMBI, 2015) developed a tool to monetise the value of multiple benefits while the mBenefits approach (Frederic Berger, 2021) helps businesses to incorporate energy productivity improvement value into strategic decision making. Such approaches build upon earlier attempts by scholars to identify and quantify productivity benefits from the adoption of energy efficiency measures (Nehler & Rasmussen, 2016; Worrell et al., 2003).

Figure 4 outlines major multiple benefits a business can capture from energy productivity improvement. Shifting the focus from energy efficiency to energy productivity transforms the focus of energy conservation and emissions reductions to consider overall business, system, and societal value, which is worth far more than just the value of energy savings.



Multiple benefits associated with industrial energy productivity measures.

Note:

*OEE is Overall Equipment Effectiveness, and

**OLE is Overall Labour Effectiveness.

Based on (Nehler & Rasmussen, 2016; Skumatz & Dickerson, 1998; Worrell et al., 2003)

Impact of energy productivity on a broad range of societal factors.

Based on (Campbell et al., 2014).

Figure 4. Two different perspectives on the multiple benefits of energy efficiency that reflect how energy productivity delivers 'multiple benefits'.

1.2.2 Value chains – beyond individual businesses and supply chains

Identifying the multiple benefits across complex and interdependent sets of processes and business in food production and consumption systems may be facilitated by a value chain approach. The start to end process of food services is usually broken into participants and processes upstream of the final point of retail sale (typically referred to as the supply chain) and downstream, to end of life customers.

Porter (2001) illustrates the traditional value chain model which involves each participant focusing most on immediate inputs and customers, while placing little or no emphasis on participants further upstream or downstream. We have broadened our analysis beyond the primary activities of an individual business, extending our lens of analysis beyond immediate inputs and customers to support considerations such as inbound logistics, operations, outbound logistics, marketing and sales and after-sales service, to include support activities such as firm infrastructure, human resource management, technology development and procurement. The main elements of the lifecycle of a product or process from farm to final consumption, as shown in Figure 3 is also encompassed, making value chains "*an integral part of strategic planning for many businesses*" (WBCSD, 2011).

The value chain approach taken in this study implicitly supports a focus on broader systems and interactions between their elements which can be useful for identifying the multiple benefits within the value chain and within supporting systems. As outlined in a recent United Nations Environment Programme report (UNEP, 2021), this shift brings five key benefits as it:

1. **Holistically** identifies all key stakeholders, the processes, material and information flows and related factors such as political, economic, social trends.
2. **Systemic** understanding of a value chain as both within and part of a system, considers the interrelationships between all the parts, their operations and how the drivers influence each one and the whole.
3. **Relatable** as it considers natural resource usage within dependencies on ecological, social, pollical and economic systems.
4. **Actionable** as science informs decision making where changes in the value chain can optimise sustainability of the entire value chain.
5. **Replicable** as the method and outcomes can be applied across scales (Figure 5):

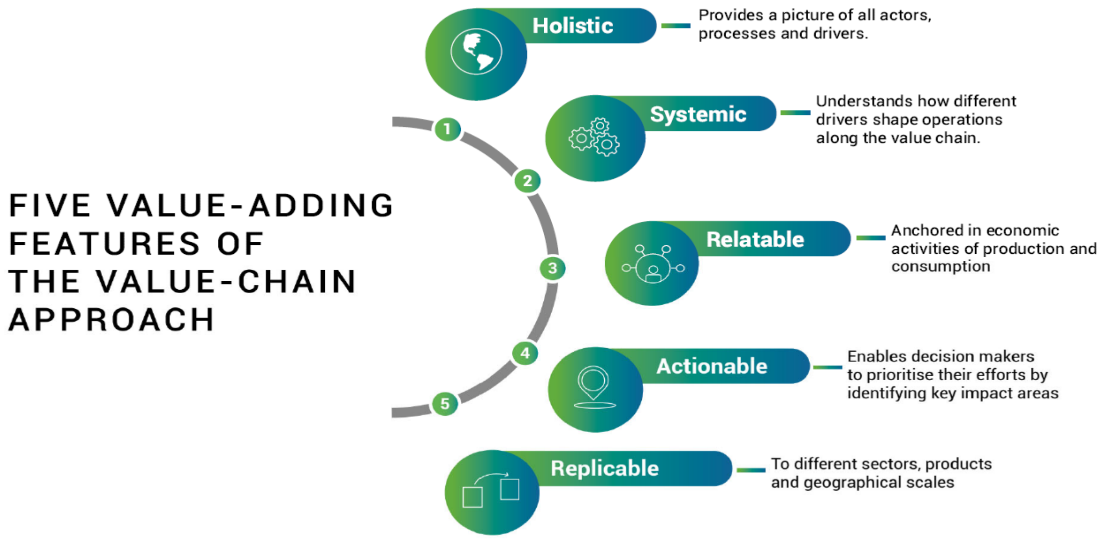


Figure 5. United Nations Environment Program (2021) explanation of the reasons for applying a broader value chain approach.

A value chain approach aims to include the broadest set of organisations as participants and views them as all interdependent parts comprising the production and consumption system. This:

- encompasses downstream processes and decisions such as distribution to end consumers, post purchase consumption and/or disposal.
- focuses on the interdependence of all participants upstream and downstream and the flows of materials, information, energy, and money.
- focuses on the fundamental issue that the largest proportion of money shared among supply chain participants comes from end consumers.

It is important to note the multiple implications that the actions of each participant have on other actors, and also for the amount of money end consumers pay. This is distributed among the participants in the supply chain and is influenced by the perceived value placed by end consumers on food and associated services.

Differences in specific key performance indicators (KPIs) to measure relevant initiatives, visible costs and benefits, ignorance of innovations and cultural factors mean that there are many energy and business inefficiencies at interfaces between organisations and within participant organisations. As the RACE for 2030 Industry 4.0 Opportunity Assessment report noted, innovations such as digitalisation and improved technologies, as well as emerging business and market models that can capture value that was previously not quantified or monetised, imply the existence of many emerging opportunities to deliver multiple benefits through energy productivity improvements (Trianni et al., 2022). Value chain approaches can facilitate cross-business and intra-business unit co-operation, secure transfer of information and money, and support optimisation of systems and practices.

Figure 6 illustrates the food value chain and highlights the potential for shared benefits enabled through digital (Industry 4.0) and distributed systems that potentially optimise information flows to all value chain participants opening opportunities for systems perspectives.

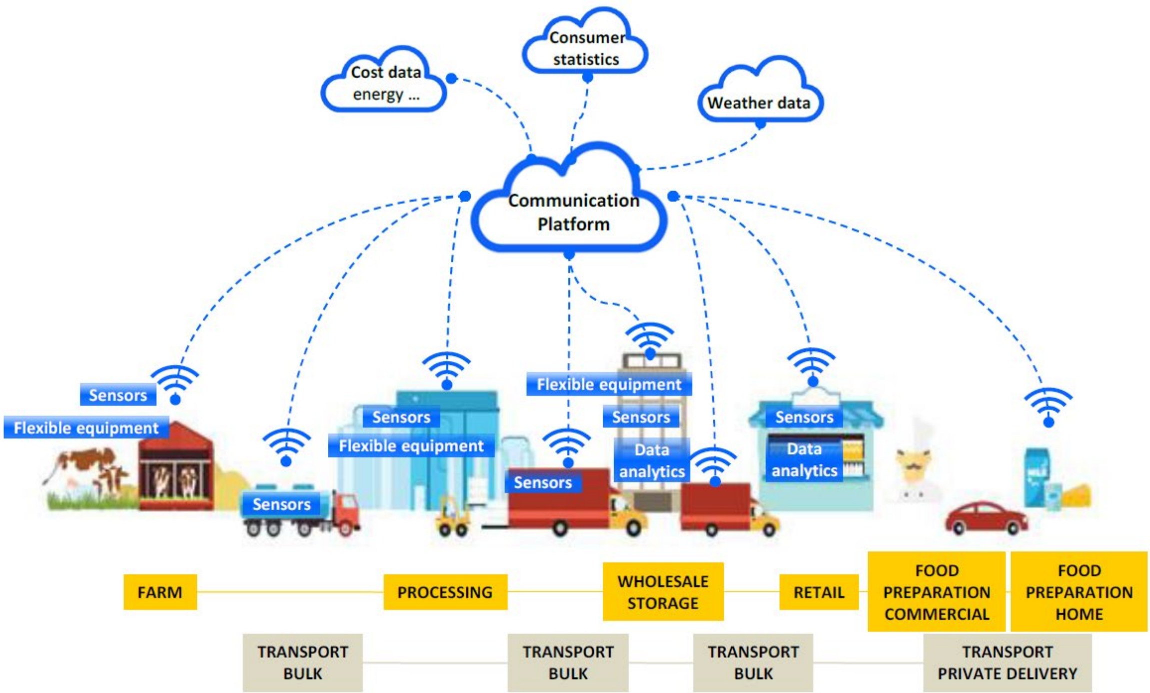


Figure 6. Industry 4.0 digital transformation underpins energy/resource efficiency/productivity at multiple levels within and between organisations in the food value chain. (Source: Jutsen et al., 2018)

To conclude, a value chain represents a broad but relatively comprehensive picture of the key participants and system boundaries of a partial life cycle assessment (LCA), although not specifically addressing energy use, carbon emissions and other impacts of direct participants' inputs. In this way, this approach offers significant advantages over LCA, being simpler and easier to communicate, while still illustrating the key relationships, interdependencies and flows between participants.

1.2.3 Systems Innovation Approach

Enabling energy productivity across a value chain relies on a shift from thinking about change in parts of the chain to considering changes across the system of interrelated processes and practices. Driving such change is inherently complex and involves influencing multiple factors. The food value chain is a particularly complex system, so this model was particularly suitable for this research project.

Over the last few decades, empirical and theoretically grounded frameworks have been developed that attempt to understand how systems change, and what hinders or helps development, influenced by thought leaders such as Frank Geels (Geels, 2002) and Donella Meadows (Meadows, 2008). These frameworks are based on innovation studies, evolutionary economics, and institutional and evolutionary theories that are well suited to understanding the complex systems change needed for working across food value chains.

Systems change happens when a system's multiple, interconnected elements — technology, people, culture, markets, policies, and environments — reorient and adjust in non-linear ways, to allow for emergent solutions and new ways of working to scale and diffuse.

Tipping points can be created when complex adaptative systems cross critical thresholds, where a relatively small change can trigger a larger change. Sensitive intervention points are interventions that create 'kicks' or 'shifts' in a system to deliver rapid impact (Farmer et al., 2019). Over time, such interventions that happen across multiple levers of change, create new system effects that become dominant, assuming the role of the new norm). These are shown as Levers of change in Figure 7 and include technology, data, policy & regulation, skills & capabilities, business models & demand, people communities & networks, finance & investment, organisational culture strategy & governance, production systems, physical systems & environments, knowledge & information flows, and market structure.

Figure 7. Levers of change (Deep Demonstrations, 2023)

Levers in this model can be considered as focus areas for enabling benefits, while also highlighting within the current systems potential barriers to and drivers for the realisation of potential benefits offered through changes of some form. Further, the relationships and interdependencies between elements in the model are not considered causal or fixed but offer a framework through which we can make sense of potential thresholds for enabling new system effects.

While systems change theories are well established, practical knowledge and approaches that support the design of targeted system interventions aimed at accelerating systems change are still emergent. Climate-KIC Australia's systems innovation approach (which is influenced by EIT Climate-KIC's deep demonstration approach in Europe (Deep Demonstrations, 2023)), fills this gap by helping to identify how changes or interventions across individual or multiple levers of change can reorient and re-shape systems. When applied through an action research approach, the framework provides a flexible means for collaboration or cooperation across a system and at the same time informs researchers about the blockers and enablers that participants in the food experiences as they deliver critical services for food production and consumption. Through our action research methodology (see section 2 for details), participants were engaged at multiple points during the research process and qualitative analysis of interviews and focus groups enabled the research team to understand the complexities of enabling energy productivity in food value chains. Action research can take various forms and so the following provides an explicit statement of the guiding principles for this action research design:

- *'Work with systems'* examples include place-based, social systems or across value chains and is collaborative in nature.
- *'Take a portfolio approach'* across levers of change (as shown in Figure 4), recognising that systems change is not built on single solutions or technical improvements.
- *'Learn by doing'* through experimentation and exploration, recognising that systems are dynamic and ongoing learning of the portfolio helps to inform what's needed, where and why.

While some research has presented cases whereby small changes in policy design can influence systems transitions through 'kicks' or 'shifts', the application of a systems innovation model to enable learning and coordinated approaches to multiple levers within a system is novel and offers a means for enabling complex systems transformations.

1.2.4 Combining the three key concepts

This research explored how these concepts could address complex changes needed for producing nourishing food that is created in decarbonised food value systems through reliable, affordable, clean energy. Looking at energy productivity through a value stream approach may reveal multiple benefits and identify technological solutions that could enable them. Taking a systems innovation approach could identify where kicks or shifts in the social-technical systems can allow those benefits to be realised and technologies to be adopted.

2 Methodology

2.1 Overview

The aim of the research was to understand how participants in food value chains deliver their services through an energy productivity and systems innovation lens, so an action research approach was selected. As previously highlighted the action research framework involves participants in the exploration of complex issues that affect them and can provide the basis for social learning that can lead to social change and transformation (Coghlan and Brydon-Miller, 2014). Specifically, the action research approach comprised the following:

- Planning: desktop research into:
  - Relevant energy efficiency and productivity measures, technologies and techniques applied or applicable to the food value chain.
  - Existing activities and organisations implementing projects within the Australian food value chain potentially related to energy productivity improvement including analysis of consumer spending.
  - Mapping relevant stakeholders across the food value chain
- Action, analysis and synthesis – Industry across the food value chain were invited to participate across the following sectors: farm production, representative industry organisations, food processing, retail and food services, warehousing and transport (n>30). All areas were represented in the interview process. Those that were available to participate in the project (n=13) were then scheduled a meeting time with the project team. Three iterative cycles through industry and research networks:
  - Interviews to understand the opportunities and barriers of embedding energy productivity across the value chain as perceived by representatives of industry and existing researchers.
  - A focus group to explore the extent to which industry perspectives and findings from our desktop research overlapped and test the level of consensus across the issues identified. The focus group also discussed a proposed approach which integrates the three key concepts - energy productivity, value chains and systems innovation – and shapes early action.
  - Socialisation of recommendations – to test a proposed strategy for a collaborative approach to implementation of energy productivity improvements in the food value chain.
- After each action research cycle the inter-disciplinary research team met to analyse and interpret the key findings and outcomes of each cycle and prepare inputs for the next cycle.
- Synthesis into final report – analysis throughout the action research process revealed where participants converged on the possible pathways for energy productivity gains based on realistic assessments of activities that were already being enabled or could be occurring across the various systems levers (e.g. knowledge, attitudes, market structures, financial flows, data, technologies, and business models etc.).

2.1.1 Planning

Desktop research was undertaken at the start of this project to assess multiple issues, such as technical and economic analysis across several potential target value chains in the food sector, and regarding energy productivity strategies (see Appendix 4) and processes to provide a basis for prioritising actions (see Appendix 1 for listing of resources reviewed).

Three streams of research were pursued within this project, which were selected based on the initial literature review and consultation with industry experts. One stream explored the nature of the food value chain, including the relationships, financial flows, environmental impacts, organisations and their potential contribution to frame a value chain model that emphasises the interdependence among participants, as well as on spending by end-consumers based on their perceptions of value.

A second stream reviewed major emerging drivers, such as reduction of energy costs, regulations, customer demand that are increasing the importance and potential value of more collaborative activity, particularly on energy productivity, across the food value chain.

The third stream reviewed energy efficiency measures, in terms of technologies and practices that could be implemented within and across the food value chain, and also investigating the range of related potential business benefits such as improved work environment, improved corporate image, better resource utilisation. In this regard, particular attention was paid to digitalisation and connection within firms and across the value chain, being recognised as important enablers of energy productivity.

These streams of research fed into the action research and application to structure the study, design the interview questions, exploring the strategies to drive energy productivity within and across the food value chain.

2.1.2 Action, Analysis and Synthesis cycles

Three iterative cycles comprised the research process which is visualised in Figure 8 (below) and summarised as follows:

1. Interviews were conducted by A2EP, UTS and Climate-KIC Australia with participants (n=13) from across the food value chain. The interviews sought to understand where individuals saw their positioning within the value chain, and their perceived opportunities and barriers to the uptake of energy productivity within their own organisations/part of the value stream and across the food value chain.
2. These participants were then invited to a focus group session where insights from the interviews were shared, and participants had the opportunity to appreciate different perspectives across the value chain, and some early recommendations were formed.
3. The group was invited to a second focus group to socialise recommendations and provide input into 'where to from here'.

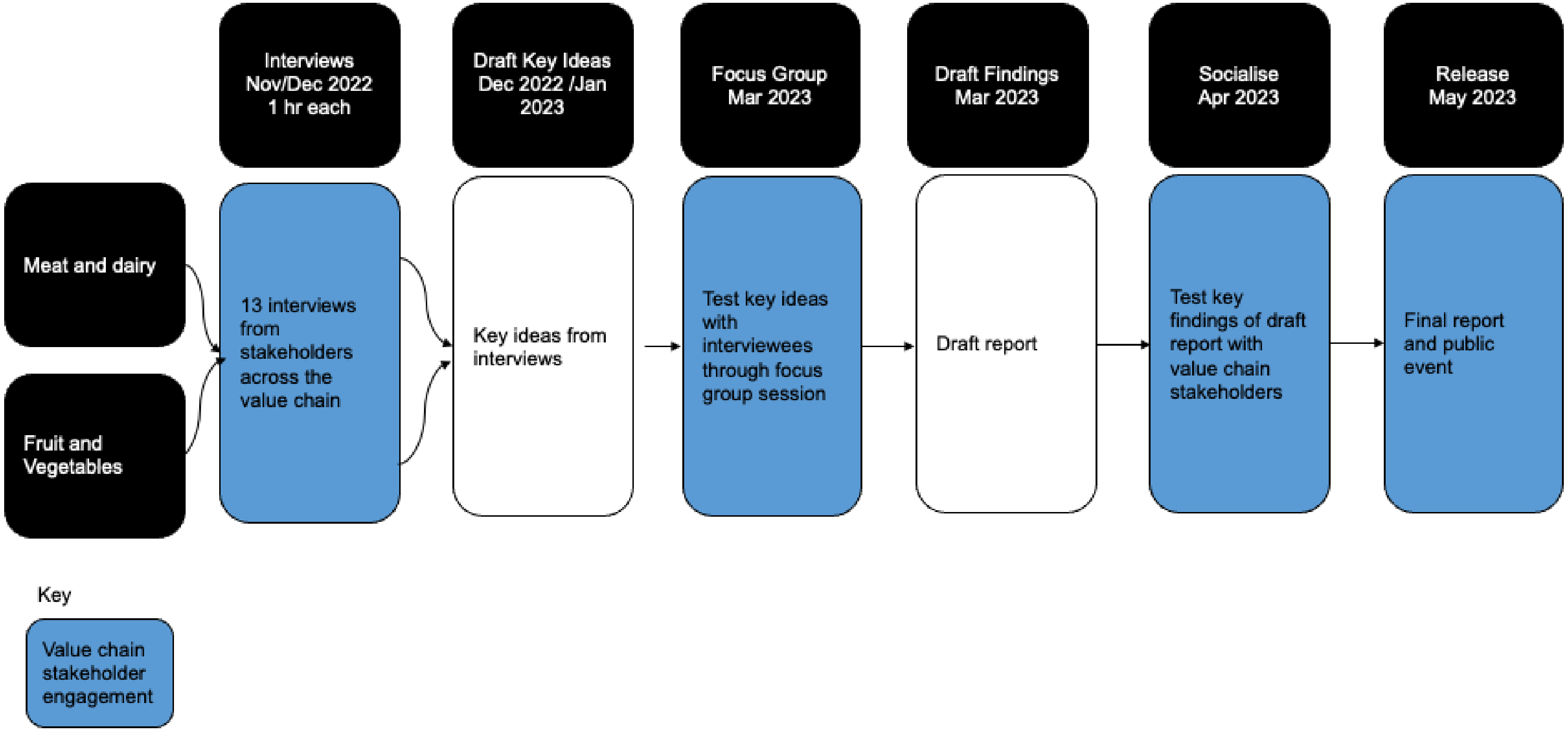


Figure 8. Consultation and engagement process

The insights from this consultation and engagement process form the basis of the findings outlined in the next section of this report.

3 Key findings

3.1 Desktop literature review

This desktop research of energy literature revealed there are substantial resources documenting examples and techniques to improve energy productivity across the food value chain, and that digitalisation (one of the key technologies within the so-called Industry 4.0 revolution) is likely to play a major enabling role across the food value chain in many ways, beyond energy productivity. It also highlighted the major importance of increased policy action on stimulating innovation, regional development, energy performance, climate response, as well as other areas to support a stronger focus on energy productivity in the food value chain. Review of literature on the priorities and activities across the food value chain led to recognition of the status of energy productivity among industry and researchers. This highlighted a case for a deeper focus on the role of the consumer in the value chain as a key enabler for market transformation towards more sustainable food production, distribution, and consumption.

3.2 Applying the three key concepts to the food industry

Energy productivity, value chains and systems innovation approaches were not widely understood by interviewees. However, when they were socialised within the focus group there was convergence of interest and general agreement that such approaches could cut through the current focus on improving individual margins and offsetting or outsourcing emissions. Potential systems energy productivity benefits through actions by individual participants that had flow-on benefits across the value chain, such as improved maintenance of food condition that reduced food waste (losing sale income downstream) or improved coordination across the value chains, such as standardised data systems were often overlooked in favour of capital investments on business expansion. Therefore, early action must build a case for the need for improved awareness and relevance of energy productivity, while working across the value chain and taking a systems innovation approach.

3.2.1 Main barriers to energy productivity

Key finding: energy efficiency and energy productivity were acknowledged as important by interviewees, but not important enough to be a high priority. This was consistent with earlier studies that identified several barriers such as lack of financing, uncertainty about return on investment, hidden cost with associated technologies, complex decision chain to uptake energy efficiency measures (Trianni et al., 2013; Hasan et al. 2019; Hasan et al., 2021). Indeed, energy productivity and its potential to deliver multiple benefits were not entirely understood, thus highlighting the need to build awareness as a key element of future action to move decision-makers towards future actions.

Interviewees also identified the following as major priority drivers of research and innovation:

- Reducing food waste at all stages in the value chain
- Decarbonising the value chain, including refrigerants, with emerging interest in Scope 3 carbon emissions (i.e. embodied emissions)
- More sustainable packaging
- Increasing the share of energy produced by renewable sources
- Reducing operational costs
- Maintaining or increasing profit margins with focus on internal activities, immediate inputs and immediate customers

Businesses did not recognise strong links between energy productivity and success in their high priority areas. We found limited understanding of the potential benefits of energy-related action beyond reducing energy costs, however they expressed their interest in exploring avenues to increase the uptake of energy productivity solutions.

Factors that undermined prioritisation of energy productivity included:

- Focus limited to reducing energy costs of an individual business. As noted earlier, energy productivity aims to enhance business value through capturing multiple benefits (details are discussed in Section 1.2.1), so it is potentially worth far more than just energy savings. Yet benefits may be shared across multiple businesses and so are difficult to capture in immediate margins.
- The implications from the adoption of energy productivity measures, going beyond energy and GHG savings, were often not recognised or sufficiently acknowledged during key decision-making processes. For example, management of refrigerants and capital costs of transition to low climate impact refrigerants will have impacts on energy efficiency and cooling capacity, but also on capital and operating costs, food quality and waste.
- The cost (and climate impact) of energy use by each participant flows through to the rest of the value chain, but it is hidden in the overall price paid for the input at each interface. The final retail price of food includes the cumulative cost of all the energy used in the value chain to the point of final sale.
- Whilst reliable energy supply is important for all value chain participants, in many cases direct energy costs are a small proportion of total costs. Thus, making changes to energy systems may be seen as a risk to production relative to potential savings. Poor communication across silos within and between businesses can also impede consideration and funding of energy productivity measures.

3.2.2 Collaborative efforts across the food value chain

Key finding: most businesses focus on immediate suppliers, their own business viability, and immediate customers, still operating as per the traditional business model. For complex and deep value chains with many participants of widely varying size and market power, this allows many inefficiencies to occur.

A new way of presenting the value chain that emphasised the potential impacts of each participant on the rest of the value chain was developed. Figure 9 qualitatively illustrates how value can be added or lost at each stage, and that the actions of one participant impact on all others to the extent that their actions add or reduce the value of the product passed on to the next stage. This was used in the interviews and focus group to encourage consideration of interdependencies and exploration of opportunities for collaborative action.

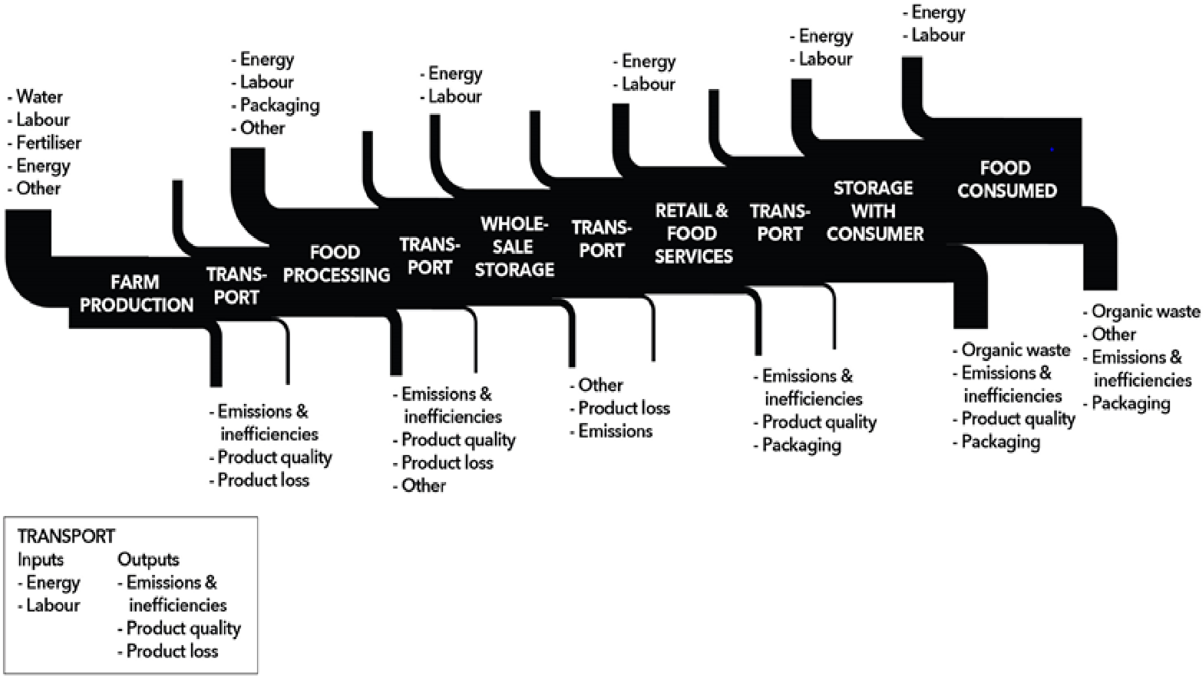


Figure 9. Flow diagram that highlights the potential for value add or loss at each stage of the value chain, and the progressive increase in value of product.

The diagram highlighted that, to overcome inefficiencies in the food system, collaborative efforts need to look across its value chain. Based on this input and discussion, project participants flagged several potentially significant areas where collaboration across some or all of the value chain is potentially important, such as standardisation and security of data and data systems, streamlining and updating of regulatory frameworks, identification and implementation of training.

3.2.3 Leveraging on a systems innovation approach to boost energy productivity uptake

Key finding: Levers of change elements were viewed as both opportunities for energy productivity gains, while also acting as barriers that preserved inefficiencies in the current value stream. To enable action, cross cutting strategies will need to be explored.

As part of the project, barriers and opportunities identified by participant interviews and/or by the research team were mapped to Climate-KIC Australia's levers of change framework to support the development of a path forward. Through this mapping activity, the research team observed a 'portfolio approach' organically being formed which covered many of the levers of change (as shown in Figure 10). This approach resonated with participants of the focus group, as way to practically create more rapid transformation of the system.

This framework also shows the complexity of real-world change and innovation that must be managed for success. This makes it clear that appropriate resource allocation and collaboration across the food value chain will be fundamental to future success in driving energy productivity improvements across the food value chain.

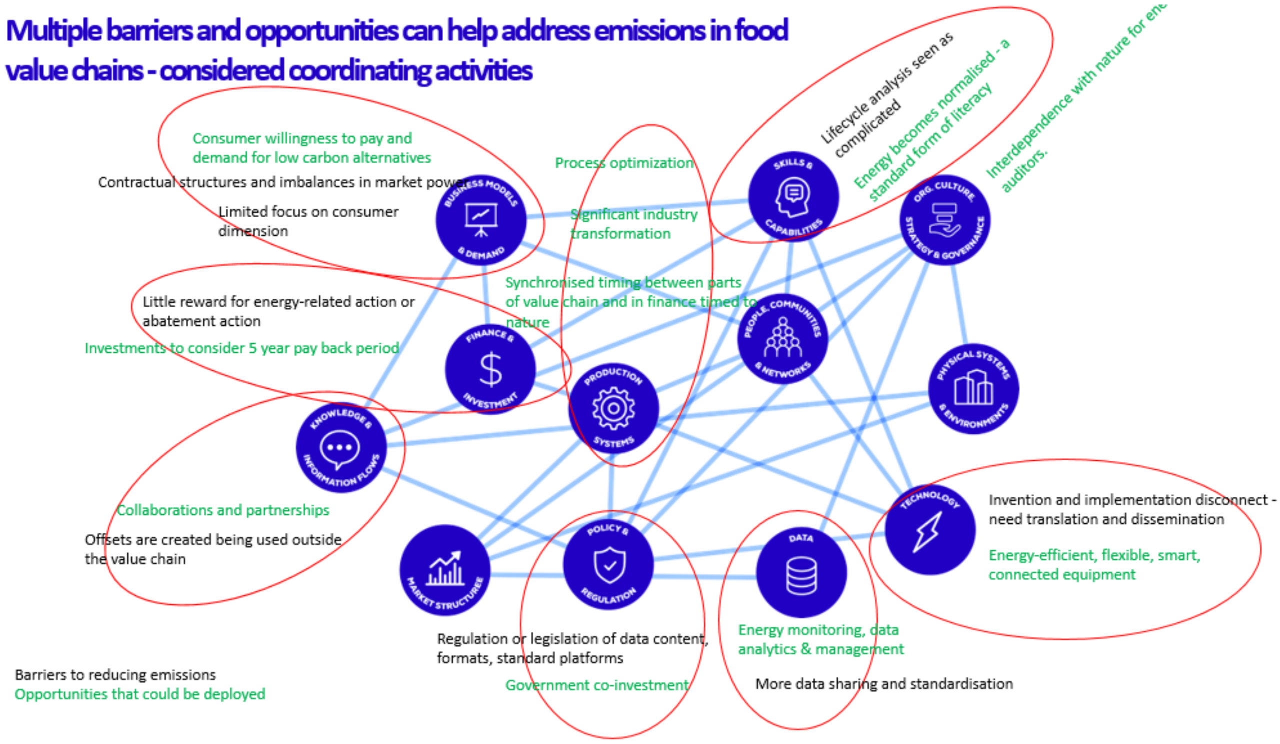


Figure 10. Climate-KIC Australia's levers of change framework with barriers and opportunities overlayed

Emerging opportunities with potential to enable energy productivity gains through collaboration were identified both in the literature review and confirmed by the interviews/focus group as opportunities. Furthermore, we found that changes in one lever could be catalysed through coordinated changes in other levers which we outline briefly below:

1. **Increasingly ambitious decarbonisation commitments and obligations.** This issue touches on most of the levers for change, so it is not surprising that it is a high priority. Most businesses in the food value chain are building knowledge about their carbon footprints, documenting Scope 1 and 2 emissions, making decarbonisation commitments and implementing actions. For larger businesses, there is increasing focus on Scope 3 emissions which are the indirect greenhouse gas emissions that occur as a consequence of the activities of a facility, but from sources not owned or controlled by that facilities business (NGER, 2022) this increases pressure to collaborate. Much of the focus is on methane from food production and waste, and global warming impacts of refrigerants (which has serious implications for costs and performance of refrigeration). Renewable energy and carbon offsets were mentioned as potential options.
2. **Circular economy (CE) industrial models.** The principle that 'there should be no such thing as waste' underpins CE. Organising food value chains that minimising waste and finding ways to transform waste into nutrient inputs, useful products or potentially valuable resources that markets will consume make collaboration and development of new business models more important. While it is early days, transitioning to CE potentially relies on changes within every lever with catalysis being enabled through business models, technologies, policy and regulation, information flows, production systems, market structures and investment and finance.
3. **Digitalisation and connection.** Real time, meaningful knowledge supports optimal action. Applying it across businesses helps to identify 'frictions', inefficiencies and contradictions between KPIs and

perceptions of what is important. These technologies are levers that are transforming data systems, technologies and production systems and potentially transform business models.

4. **Consumer focus.** Consumer perceptions and preferences are fundamental drivers of the food value chain, and they influence or are influenced by many of the levers for change. A consumer focus is enabled through a targeted value proposition for the end consumer, yet most businesses were still more focused on the concerns of their immediate customers in the value chain. Spotlighting consumer needs through the business model lever would be leveraged alongside changes in data and information flows that enables greater transparency to inform consumer choices and the changes in societies and communities food preferences which was greatly under looked.

5. **Investor and government focus on environmental performance is increasing.** Not all participants saw strong signals such as financial incentives or consumers prepared to exert pressure for change through government policies. Investor perspectives drive access to finance and reflect broad emerging issues that shape business priorities and hence most of the levers. Government policy directions can shape most of the levers through multiple policy options. Federal and other governments are expanding policies and programs related to energy productivity and the terms of reference for Australian Renewable Energy Agency (ARENA) and Clean Energy Finance Corporation (CEFC) have been widened to include energy efficiency and productivity measures. This provides an opportunity for the food value chain to seek funding.

6. **Energy productivity technologies narratives and new business models.** As noted earlier, the project identified limited focus on energy productivity, so there is a need to build understanding and awareness, as well as capacity to apply relevant measures. Government policies, technological innovation, training and infrastructure drive many levers for change. Industry associations such as A2EP and the Energy Efficiency Council (EEC) are building capacity, while government policies on electrification are building innovation capabilities and skills.

7. **Potential to partner with, build on or complement existing work by applying an 'energy productivity lens' and building greater awareness of how it can help them to achieve their existing and additional objectives.** Greater knowledge and information flows could be enabled by creating partnerships with organisations that are already generating knowledge sharing platforms. Collaboration could leverage existing technologies, data sharing platforms and reduce resourcing constraints.

In the next section we provide our synthesis and pinpoint several cross-cutting opportunities. More details on specific aspects of these issues are included in Appendix 1.

4 Discussion and Conclusion

During the project it became clear that a lot of valuable research, innovation and delivery regarding energy related issues was occurring – but it was not perceived to be related to energy productivity improvement. As a concept, energy productivity is not well understood and there is a need to build awareness and to demonstrate how it can deliver multiple benefits that food industry businesses value. To do this, it is recommended that a Consortium is formed which aims to drive action across the food value chain and use a systems innovation approach framing. A range of opportunities have been identified that sit across levers of change. Rather than operating in a silo, there is potential to drive energy productivity improvement by working with and building on existing organisations and activities. The challenge is to integrate energy productivity into existing activities and expand their scope. For this reason, we have highlighted the need to pursue coordinated and synergic high-impact opportunities (Section 4.1). However, to allow a Consortium to succeed in building awareness of energy productivity gains and effectively drive transformation, a draft one-page cascade strategy has been proposed in Section 4.2, with further details on recommended actions.

4.1 Pursuit of coordinated and synergic high impact opportunities

This section discusses the cross-cutting systems levers (outlined in section 3.2.3) where the participants focussed their attention during the focus group, and from our desk research findings, which identify other opportunities that could potentially accelerate action on energy productivity within the food value chain. This section provides an evidence base to generate recommendations for future collaborative energy productivity projects and activities.

We found that substantial research, development and innovation is occurring that potentially involves energy productivity. However, most of it is at the individual business or industry category level. Where cross-cutting initiatives are underway on LCA and supply chain projects, most of the focus is on food waste or specific processes. There is a need for stronger links between energy productivity researchers and the food industries.

Energy is consumed at various stages of the food supply chain, including farming, harvesting, transportation, packaging, and storage. When food is wasted, not only are the resources used in producing, processing, and transporting the food wasted, but also the energy that went into these processes. For this reason, by extending the shelf life at retail points, but also of food in homes, less food is wasted, leading to reduced energy consumption and increased energy productivity. Such reduced food waste in turn can indirectly contribute to energy productivity by reducing the demand for new food production that requires other production resources such as water, fertilisers, pesticides, and fuel for machinery. By minimising food waste, the need for additional energy-intensive food production can be definitely reduced.

There are clear synergies between the opportunities identified in the previous section that justify a stronger focus on collaborative application of energy productivity initiatives. For example, action on increasingly ambitious decarbonisation commitments and obligations (Scope 3 carbon emissions) and development of circular economy models both rely on cross-value chain data (fostered by improved digitalisation and connection) to facilitate reporting and identification of priorities, as well as to support action through tracking, optimising and secure sharing of data and financial transactions. Adaptation to climate change is deemed to impact on different value chain participants, such as agricultural producers and transport operators, in different ways. These may incur new costs or change business models in ways that must be understood and adapted to by others in the value chain.

Consumers will play a key role in ways that have not been a major focus by supply chain research. Not only do they consume a lot of energy, but all their decisions and behaviour with respect to e.g. purchase of appliances, food choices, and their attitudes in response to supply chain actions regarding climate, together with the emergence of new business models and appliance manufacturers-retailers interactions, will matter. A good understanding of their behaviour, attitudes, motivations and likely reactions will therefore become crucial for the whole food supply chain. Effective information, education and empowerment strategies will be increasingly important.

It makes sense to adapt and build on existing data resources, networks, organisational frameworks and projects rather than risking duplication and incurring unnecessary costs. However, this will require leadership, resources, infrastructure and cooperation that addresses energy productivity as a provider of solutions and multiple benefits. The emergence of the Materials and Embodied Carbon Leaders Alliance (MECLA) which focuses on reducing embodied emissions in building materials is an example of a collaborative group of suppliers and major customers that is making significant progress.

Leveraging on existing and established networks would offer valuable synergies to improve data sharing about energy productivity. For instance, a partnership with The Fight Food Waste (FFW) Cooperative Research Centre (CRC) could offer the opportunity to extend their existing web-based tool, DIRECT, that tracks volumes, financial flows and carbon emissions across the value chain. On the one hand, since the tool incorporates carbon emissions and financial flows, it is envisaged that the underlying data could be related and useful to report on energy use and productivity across the value chain too. Also, such a partnership would support collaboration on a number of sector working groups' that are focused on sustainability challenges along the value chains. On the other hand, at present it is difficult to document and monetise the multiple benefits of energy productivity measures, especially when they cross business boundaries. Hence, the expansion of that tool could lead to the development of an Energy Productivity Multi-Benefits valuation tool, initially using the food value chain as the prototype, fed with data from FFW CRC and Food Innovation Australia Limited (FIAL).

4.2 A strategy to increase awareness and drive transformation for energy productivity

To undertake a project to identify multi-benefits while also engaging with coordinated changes across systems levers that would enable realisation of energy productivity gains in food value chains, a consortium-based approach is recommended. The consortium should include governmental agencies, business leaders (both in the manufacturing, distribution and retail), industry associations and groupings, as well as consumers in the food value chain and researchers, guided through a broad strategic approach.

A cascade strategy attempts to layout a pathway for a consortium to take action to increase awareness and drive transformation for energy productivity. Cascade strategies are deliberately high-level and should be co-created by those enabling systems innovation for energy productivity in the food value chain, as and when they commit to such an endeavour in response to lessons learned, funding accessed and realities of who participates. Within the cascade strategy, three follow-on actions were identified, which are explained in more detail below.

Vision	Energy productivity (EP) gains deliver multi-benefits through systems innovation capabilities and cross-cutting policy mechanisms to leverage procedures and technologies to decarbonize food value chains and capture business value.		
Values	EP enabled systems innovation secures food sovereignty	Responsible food production and consumption enabled through EP gains	EP gains have multi-benefits in sustainable food production and consumption systems
Focus areas	Set policy framework for cross-cutting systems levers that enable competitiveness, avoid price volatility, and reduce emissions while removing barriers and market distortions	Identification of demand-side mechanisms that will expedite kicks and shifts in energy productivity improvements	Capability development for leading systems innovation through supporting infrastructures, technologies and new business models – co-designing and testing prototypes to generate data on sustainability and multi-benefit indicators

Objective/s

1. Build motivated consortium to champion energy productivity gains as an enabler of decarbonization by developing capabilities and showcasing best practice
2. Demonstrate and communicate the narrative about the high value opportunities for energy productivity gains across food production and consumption systems that create shared value and enhance energy performance
3. Identify and track the multi-benefits gained across the value chain through implementation of technology and process related improvements for energy performance
4. Account for GHG reductions in energy productivity gains across a value chain as part of National Determined Contribution – net zero by 2050 and reduce Greenhouse gas emissions by 43% from 2005 levels
5. Evidence multi-benefit metrics for basis of innovative funding mechanisms to scale growth of energy productivity solutions

Key Projects

1. Establish Consortium and engagement mechanism with cross value chain participation
2. Take a systems innovation approach and coordinate of portfolio of actions levers of change, linking to existing work where possible
3. Adopt a continuous capability development and learning approach across Consortium memberships and develop specific EP toolkit and training for enabling capability development.

Measures of Success

Motivated group established who are overseeing implementation of EP gain projects supported by coordinated systems innovation.
Levers identified that best enable multiple systems benefits in form of emissions reductions, financial and nature positive benefits and livelihoods and wellbeing for value chain participants
Embed and raise profile of EP multi-benefit indicators through partnerships with FFW and other alliances.

Figure 11. Energy Productivity Cascade strategy

4.2.1 Action 1: Establish a Consortium and engagement mechanism with cross value chain participation

No single organisation can raise the profile and drive transformation of energy productivity in the food value chain by itself. On this basis, the project team recommends the creation of a Consortium to lead the change. The aim of this group is to lead/consolidate/evolve the areas of focus in the cascade strategy and set a roadmap to enable continuous systems innovations required for enabling energy productivity gains.

The consortium would co-develop infrastructures, resources and capability development methods for the public benefit and so is well suited initially for government investment. Membership of the Consortium should be made up of representation of:

- **Food value chain** – industry influencers from multiple parts of the food value chain (e.g. leading transportation companies, retailers who are driving action and representatives of end consumers) and other organisations who are already engaged in action across the food value chain (e.g. Agrifutures).
- **Energy productivity** – organisations such as A2EP and EEC have a deep understanding of energy productivity and can offer expertise to run a secretariat and design and pursue effective system interventions that supplement existing capacity in groups like FFW CRC, FIAL, Agrifutures, Universities, etc, and develop practical demonstrations.
- **System innovation approach** – Climate-KIC Australia brings its systems innovation approach to help the consortium structure its work as a portfolio of action that learns and grows over time.

4.2.2 Action 2: Adopt a systems innovation approach and coordinate a portfolio of action across levers of change

This report suggests several opportunities that could be pursued across the following cross cutting levers of change:

Table 2. Opportunities in the adoption of a systems innovation approach using cross-cutting strategies.

#	Cross-cutting strategies	Rationale	Potential actions
1	**Increasingly ambitious de-carbonisation commitments and obligations**	As organisations move towards baselining and understanding Scope 3 emissions, enhanced data collection and sharing across the value chain will be critical.	Establishing partnerships and synergies for the co-development (e.g.with other existing or emerging CRCs as detailed in sub-section 4.1) of tools for simultaneous tracking of volumes, financial flows, energy productivity and carbon emissions across the value chain.
2	**Circular economy industrial models**	The tight coupling between industrial and ecological systems in the food value chain relies on symbiosis between natural and technical systems design.	Consortium could look for business models which focus on the end customer needs while also optimising biological nutrient regeneration across the value stream, powered by renewable energy inputs, and viable business models that utilise recovered resources.
3	**Digitalisation and connection**	Standardised data, metrics and benchmarks enable transparency and information flows to inform better decision making that can expedite decarbonisation and regeneration.	Pilot - development of Energy Productivity Multi-Benefits valuation tool, initially using food value chain as the prototype. Research adoption of digitalisation and connection in Australian and other economies to support optimal adoption.

#	Cross-cutting strategies	Rationale	Potential actions
4	Consumer focus	As noted in Section 4.1, there is substantial potential to extend shelf life of food in homes and reduce consumer waste which is related to energy productivity. Research into methods of maintaining food temperatures and conditions during transport to homes, as well as advances in refrigeration to improve preservation and feedback on actual food condition for householders. Cooking and management of leftover food and waste are areas for action.	Pursue further research into methods of maintaining food temperatures and conditions during transport to homes (known as the cold chain), as well as advances in refrigeration to improve preservation and feedback on actual food condition for householders. In addition, develop cross-disciplinary research to engage appliance manufacturers, food technology and social scientists to explore improved monitoring of performance of refrigerators and feedback to households. Participants in the food value chain could contribute to extension of shelf life e.g. by design of packaging, but at present they seem to have limited incentives to do so: lack of real-time data is a factor, as is lack of consumer 'pull' based on awareness of how much potential there is for improvement.
5	Investor and government focus	The Federal Government is currently developing policy around 'energy performance' and this provides an opportunity for a Consortium to increase the profile of 'energy productivity' in the food value chain by ensuring it is recognised as a key concept in this policy. This will improve awareness and future funding opportunities of energy productivity.	Create links to ARENA and the CEFC, who have broadened their terms of reference to include energy efficiency, to lay the groundwork for the funding of future energy productivity projects. There may also be potential for co-investment especially where new technology investments have flow on benefits for the entire value chain, but where the cost was unevenly burdened on one participant segment (e.g. investment in logistics improvements). Investment in internalising renewable energy generation into financing/investment models and instruments and finance mechanisms that are sensitive to seasonal variation and timing, climate risks and vulnerabilities will be important, but research is needed to make a case.
6	Energy productivity and new business models	Taking an energy productivity and value chain approach, might open new business model opportunities and investment opportunities.	To demonstrate potential, follow on research could explore opportunities through the concept of making use of idle capacity, optimising regenerative food value streams, alternative business models that allow farmers and others to gain greater market power to re-energise rural communities, and investing in restoration of supporting biological systems. A pilot project could involve development of an Energy Productivity Multi-Benefits valuation tool, initially using the food value chain as the prototype.
7	Potential to partner with, build on or complement existing networks e.g. FFW CRC, FIAL	Energy Productivity is a relatively unknown concept across the food value chain and its profile needs to be lifted. Opportunity to partner with existing groups to gain momentum.	To improve the awareness of energy productivity, follow on research or thought pieces might partner with existing alliances and explore practical examples of energy productivity, detail the 'size of the prize', and demonstrate how it is a key enabler to overcome future decarbonisation targets and capture additional business value by improving coordination, enhancing maintenance to improve reliability, optimise processes and logistics, etc.

Of the above, the first actions the Consortium might take to create kicks or shifts in the system, and which are depicted in the cascade strategy are:

- Pursue interventions related to: Policy, regulation and data, Government policies and Knowledge and information flows.
- Work with existing food industry organisations to develop project proposals to expand existing projects to incorporate consideration of energy productivity.

4.2.3 Action 3: Adopt a continuous capability development and learning approach

The Consortium will be responsible for guiding, observing, exploring and experimenting to increase awareness and profile of energy productivity. Interventions will start to change the system but there is no one silver bullet. To increase the relevance and prominence of energy productivity, ongoing work will be required to determine what's working, what's needed, where and why. Effective learning is supported by deliberate, robust and social sensemaking.

Over time an Energy productivity toolkit will be developed through the portfolio approach described above, enabling capability development across the value chain, which incorporates elements of Scope 3 emissions, circular economy, digitalisation etc. that incorporate the value of multiple benefits.

Appendices

Appendix 1: Additional information on major emerging levers

A1.1 Climate response through adaptation and decarbonisation, including Scope 3 emissions

The food value chain is very vulnerable to impacts of climate change through extreme weather and changing climates. These impact on energy use and drive capital investment in response. The food industry is also under increasing pressure to reduce its own carbon emissions and to support emission reduction by customers.

The need to adapt offers opportunities to make optimal decisions about investments and changes in practices that can impact on energy use or take advantage of energy-related innovation and digitalisation to provide data to achieve other outcomes. For example, optimisation of crop watering can be combined with improved pumping efficiency, renewable energy installations and smart management of energy to reduce prices paid. Piggeries are installing anaerobic digestion to generate biogas and creating carbon offsets (ACCUs) while gaining access to renewable energy and addressing waste management issues.

Decarbonisation is another increasingly powerful driver for energy productivity. Aggressive targets for emission reduction and carbon sequestration are being set by governments, while voluntary and regulatory frameworks are being developed and strengthened. The United Nations Framework Convention on Climate Change provides a global framework. The global Science-Based Targets Initiative (SBTI) and the Task Force on Climate Disclosure (TCFD) are driving ambitious and rigorous schemes for businesses to apply. In Australia, the Australian Prudential Regulatory Authority (APRA), Australian Securities and Investments Commission (ASIC) and others are implementing guidelines and requirements.

While renewable energy is seen by many Australian businesses as the main energy-related option, global leaders such as the European Union and International Energy Agency focus on 'energy efficiency (and productivity) first'. This approach is more cost-effective and reduces the scale of investment in energy supply infrastructure needed (Murray-Leach, 2023).

Consumers are also increasingly seeking low carbon food and packaging, as well as improved waste management solutions. In turn, they are applying pressure to or forming partnerships with their supply chains to improve performance.

And, of course, governments are ramping up targets.

An important aspect of recent decarbonisation action has been the increasing focus on Scope 3 emissions. Scope 1 and 2 emissions focus on emissions associated with activities businesses control, such as on-site activities and energy use (Scope 1) and emissions associated with purchased energy such as electricity (Scope 2). Scope 3 emissions are those associated with the inputs to a business and resulting from customer consumption and end-of-life management of products and services provided by a business.

The world-leading Science Based Targets Initiative (SBTI), which operates a leading voluntary carbon accounting and target scheme, and Australia's *Climate Active* program are requiring improved assessment and reporting of Scope 3 emissions and are considering setting targets. Recent analyses in the US show that Scope 3 emissions can be much larger than Scope 1 and 2 emissions combined, with a ratio of about 7:1 (see Figure A1.1).

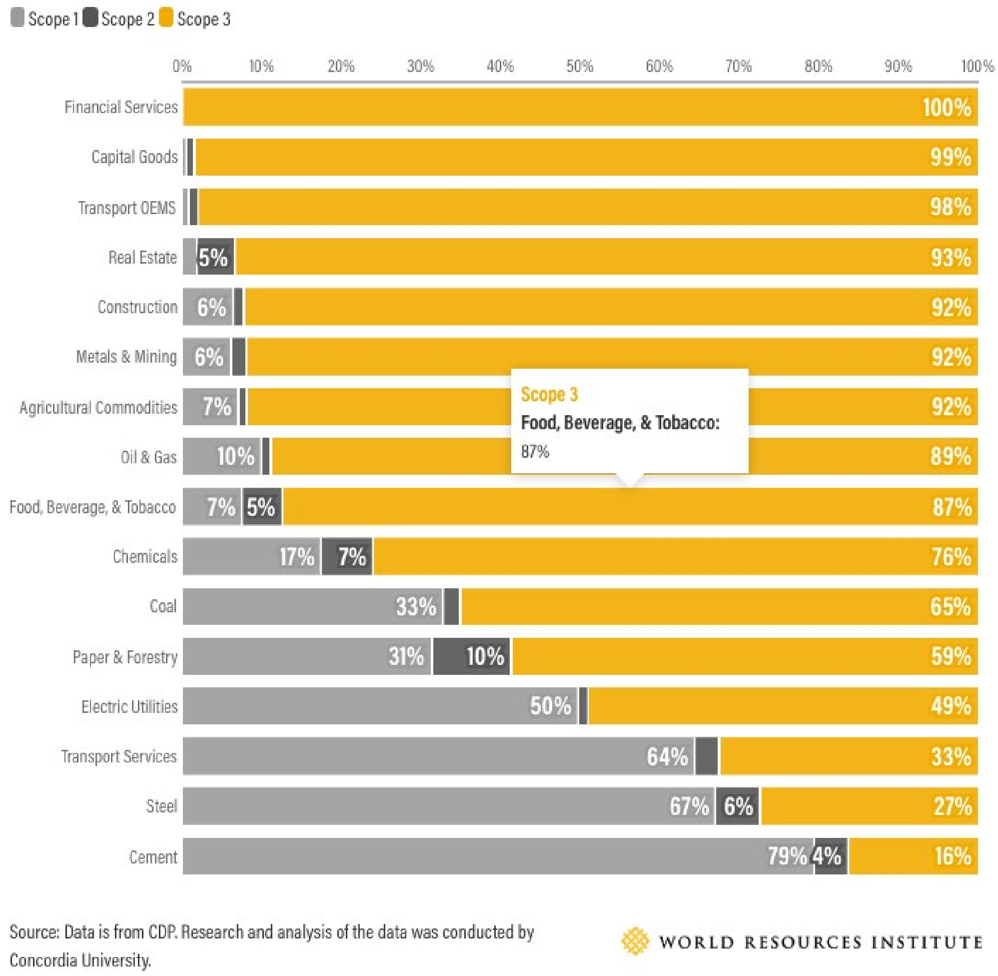


Figure A1.1. Contribution of Scope 1, 2 and 3 emissions to total emissions by sector Source: (Lloyd et al., 2022)

Businesses can only address Scope 3 emissions through cooperative action with their supply chains and customers. This offers synergies with value chain approaches and enhances recognition of the value of energy productivity improvement. An important aspect of Scope 3 emissions is that they are much larger for low energy-intensity businesses, especially those with energy-intensive supply chains and those who sell products or services with long lives or high ongoing energy consumption. A focus on Scope 3 emissions may therefore increase motivation of these businesses to collaborate on broader energy productivity measures. Major food retailers are beginning to focus on Scope 3 emissions, which will involve higher engagement with supply chains, customers and waste management systems.

As organisations move towards baselining and understanding Scope 3 emissions, enhanced data collection and sharing across the value chain will be critical.

A1.2 Circular economy: no such thing as waste

Another emerging driver of a more comprehensive approach to resource and energy management is the Circular economy model. The underlying principles of the Circular economy (CE) are that there should be no such thing as waste. Materials and resources should be circulated in the system at their highest value and nature and biological systems regenerated. Enablement of CE is dependent on new business models and redesign of production systems reliant on cooperation across supply chains and consumers so that waste is avoided, minimised, recovered, reprocessed and incorporated into useful products and services.

Both Scope 3 emissions and circular economy involve a need for collaboration across value chains, and capture and sharing of data, as well as increasing application of lifecycle analysis. For circular economy, it is important for potential recovery and reprocessing businesses to be able to generate revenues for viable business models and to build markets for their output, which has potential implications for changes in financial flows between value chain participants and process changes in existing businesses.

A1.3 Digitalisation (Industry 4.0) and connection

Digitalisation, also known as Industry 4.0, has broad business productivity benefits across all sectors, not just industry, and underpins carbon accounting and circular economy. It is another powerful driver of energy productivity, as shown in the recent RACE for 2030 report (Trianni et al., 2022). Utilisation of multiple data streams, sensors, data analytics and modern communications allow digitalisation to be a key enabler for effective identification and implementation of energy productivity opportunities, as well as the quantification of multiple benefits and tracking of value.

The potential for digitalisation, data analytics and artificial intelligence to integrate data from multiple sources, convert it into useful information and deliver it to the right place at the right time in a useful form provide enormous potential to identify emerging faults, optimise performance, provide on-site guidance for operators or repairers and many other useful roles. The International Energy Agency has published extensive studies of the potential of digitalisation to drive energy productivity and capture multiple benefits (see Turk et al., 2017).

A1.4 Consumer focus

Household and institutional consumers play important roles in the food value chain. Yet they were not often mentioned in our consultations.

Consumer spending is the main income source shared among the participants of the food value chain, the appliance value chain and energy suppliers. Consumer preferences, perceptions and behaviours are fundamental to costs and impacts of food value chain activities. This section of the report focuses on households, but institutional and food services business energy productivity performance also require more focus.

Consumers themselves use substantial amounts of transport fuel, energy, time and emotional energy as they buy, store, manage and cook food and dispose of waste food. This comprises around a fifth of primary energy used in the food value chain (Jutsen et al., 2017).

Over 40 percent of all food waste is generated by consumers – a third by households and 7 percent by institutions and food services providers (Biene et al., 2021; Brodribb & McCann, 2020) suggest that 2021 hospitality waste was double this value. Households waste 18% of the food they purchase, at a substantial cost to family budgets and an overall cost of $19.3 billion to the economy). Overall, climate impact of food waste from production and disposal is 17.5 Mt CO_2e annually. Fruit and vegetables comprise a disproportionately large proportion of food waste and associated costs and carbon emissions (Biene et al., 2021).

Consumer-related energy productivity issues have major implications for food waste as well as energy use and emissions across the value chain. There is substantial scope for change including:

- Consumer and food service industry shifts to low carbon food value chains – see Figure A2 for a breakdown of household costs for food and food related services. This shows the significance of animal products (meat, fish and dairy) and fruit and vegetables: direct purchases comprise around 30% of household food-related spending. Food services that provide meals out and fast food comprise a similar share of food related spending.
- Optimising transport from point of purchase to consumption or consumer storage, including management of food condition.
- Consumer energy use for storage and appliance purchase and maintenance: for example, Miele claims its refrigerators extend storage life up to three times. Storage conditions impact on energy, emissions and cost of food waste, shopping transport, and health costs.
- Food preparation, including decisions regarding preferred technologies and cooking practices, and minimising food waste.
- Management of prepared food, such as portion size, uneaten food on plates, excess prepared food (e.g. freezing, disposal, feeding to animals, composting, etc).

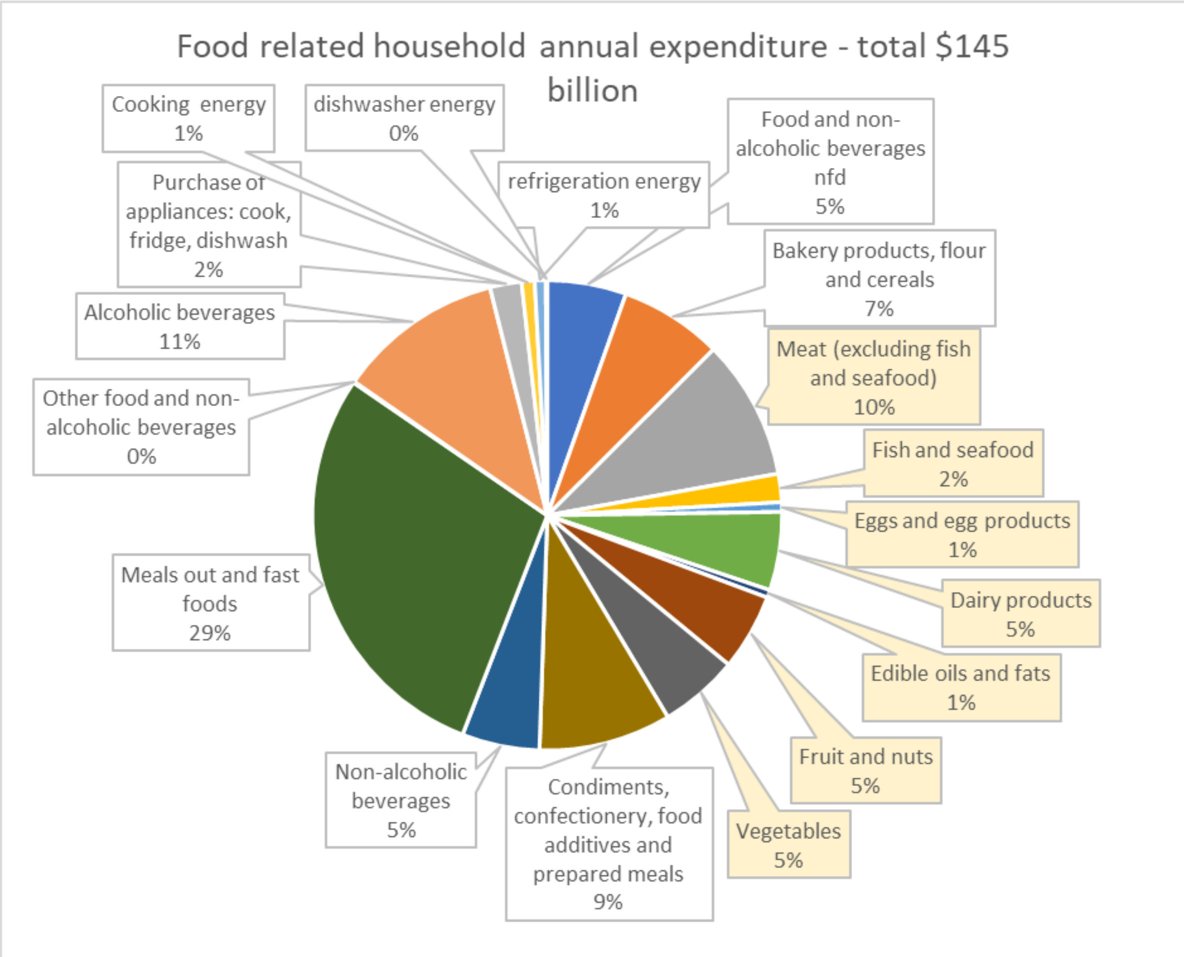
The consumer area is an example of a situation where many consumer decisions and practices that relate to energy productivity do not recognise it. For example, the recent popularity of air fryers has been driven by convenience, food taste and meal management. Their potential to halve cooking energy use and reduce impacts on home heating and cooling energy relative to a conventional oven is rarely mentioned.

An improved understanding of the role of food-related energy productivity could lead to changes in appliance design, consumer decisions and practices. For example, a FFW CRC project is monitoring real world energy consumption, temperatures and usage of household refrigerators.

A range of policy tools could be applied to support change in technologies, business models and consumer behaviour. Social and technical research is needed to understand the situation and explore options for change.

Consumer information can influence consumer attitudes and behaviours including food purchasing, food management and preparation, and appliance purchasing. Many options exist, such as government or industry run advertising and information resources, various forms of food labelling and engagement programs in schools, communities or other target groups.

Labelling exists for food health (e.g. Australia's star rating scheme (Health Star Rating, 2022), and appliance energy performance (Energy Rating, 2023) for refrigerators and dishwashers, (Topten, 2023) for ovens, induction hobs, range hoods, coffee machines, refrigerators and dishwashers). Consumer organisations such as Choice provide extensive information, while energy and environmental sites offer advice on food-related appliances and practices.



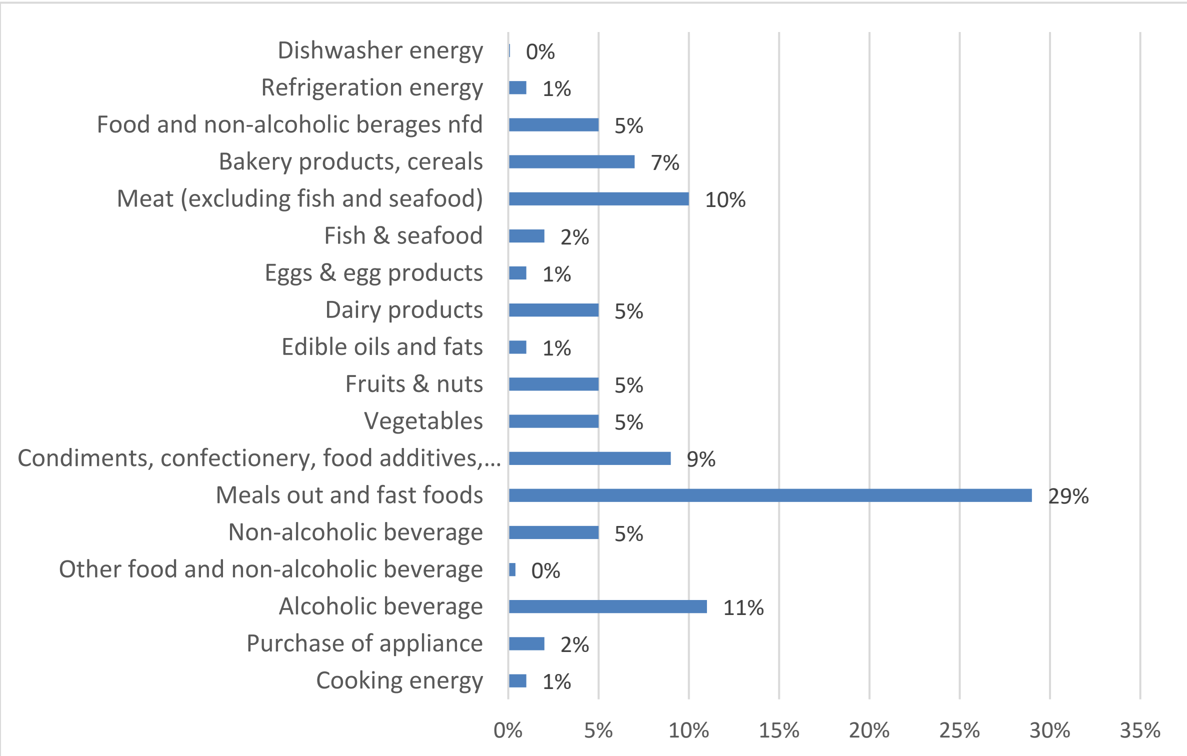


Figure A1.2. Potential breakdown of food related household annual expenditure.

Figure A1.2 shows the annual expenditures by households on food related products and services, including household energy and relevant appliance purchases. These expenditures can include many other factors besides food, such as packaging, labour etc. The chart has been created by drawing together several sources of data as follows:

- **Expenditures**. Costs were adjusted to reflect changes in population since 2015-16, however excluding inflation. Source: (Household Expenditure Survey, 2017)
- **Appliance energy use data**. Source: (Residential Baseline Study for Australia and New Zealand, 2022). Assumptions: Electricity price: $280/megawatt-hour; Cooking gas price: $20/Gigajoule; Gas share of cooking energy: 30%.
- **Travel for food shopping**. Author's estimate based on (Hagberg & Holmberg, 2017), assuming 10 km/week food-related travel.

There is increasing interest globally in environmental labelling of food. One source commented that:

'*There are now almost 460 eco labels globally, with over 120 different types of front-of-pack labels in use on food and drink products, offering to provide shoppers with greater information about the environmental footprint of food*' (Morrison, 2022).

There seems to have been limited discussion in Australia regarding environmental labelling of food. Industry responses to this issue (FRSC, 2021) emphasised voluntary approaches.

There is ongoing discussion of use and interpretation of 'use by' and 'best by' labels, which can impact on real world shelf life and, in turn, energy use and food waste and management across the value chain and related climate impacts. Food condition sensors may provide more reliable information (Barandun et al., 2019).

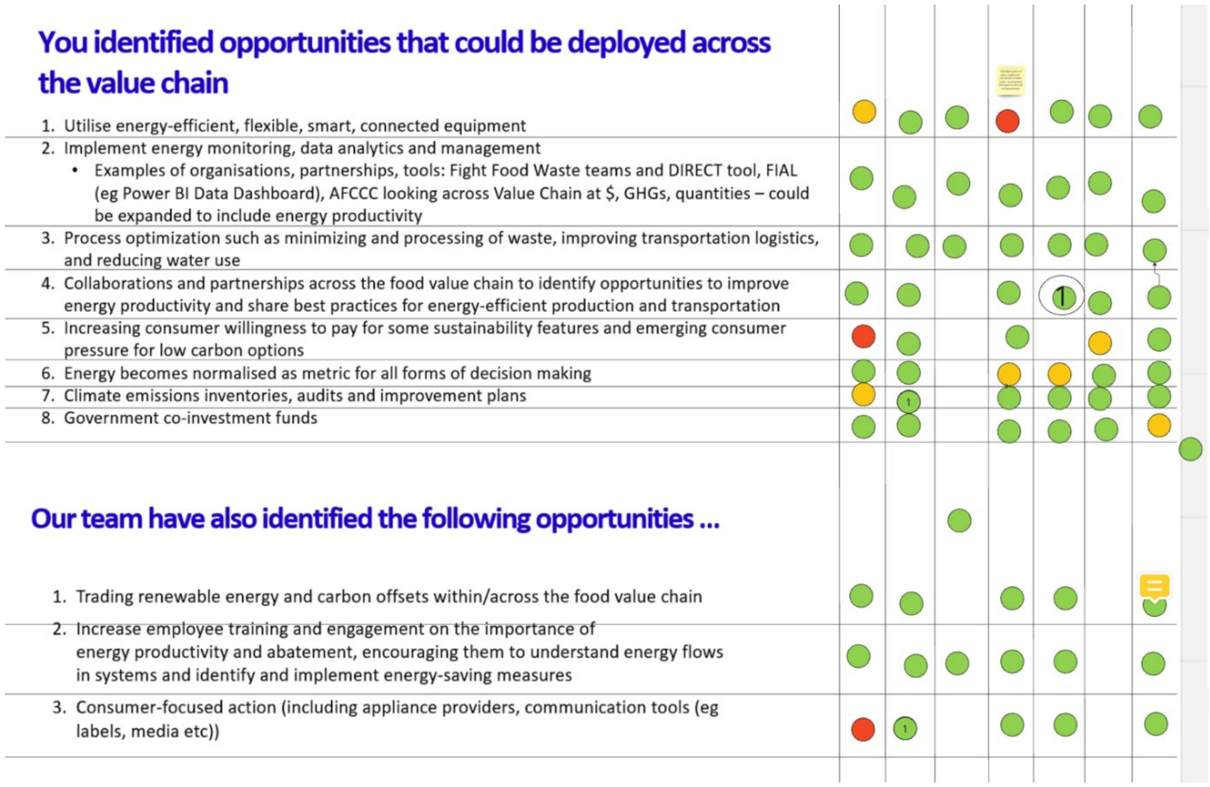
Only one of the food industry people consulted in our project mentioned climate (or energy) impact labelling as an option. Given these outcomes, it seems that environmental food labelling will have to develop initially as a voluntary scheme in Australia, focusing on food types where industry and/or community are most concerned. If it gains traction, it may progress to mandated status.

A1.5 Energy productivity technologies and business models

Taking an energy productivity and value chain approach might open new business model opportunities. To demonstrate potential, research could explore opportunities through making use of idle capacity, optimising regenerative food value streams, alternative business models that allow farmers and others to gain greater market power to re-energise rural communities, and investing in restoration of supporting biological systems.

Appendix 2: MIRO results from focus group

These excerpts from the MIRO board used during the focus group session show the responses of participants to our team's summary of opportunities identified by interviewees and through our research.



Appendix 3: Summary of desk research sources

Desktop research synthesised related research and identified data sources, including:

- Early A2EP work on the Food Value Chain (Jutsen et al., 2017a; Jutsen et al., 2017b)
- RACE for 2030 Opportunity Assessment Value Chain (B1) report (Transforming energy productivity through value chains. Final report of opportunity assessment for research theme B1) and associated documents and analysis (Denham et al, 2021)
- Household Spending data (ABS, 2023)
- Revenue and value-added data from CSIRO, ABS, DAFF
- RACE for 2030 CRC Industry 4.0 for energy productivity – Opportunity Assessment for Research Theme B2, Final Report, (Trianni et al, 2022)
- CSIRO analysis of future paths for the Australian food sector (Wynn & Sebastian, 2019)
- Activities of the Fight Food Waste CRC (FFW, 2023) and FIAL (Biene et al., 2021)
- A review of recent literature on technologies and opportunities to improve energy productivity in the food value chain and application of value chains and potential synergies between emerging drivers of change within the food value chain (for details see Appendix 4)
- A literature review of relevant energy productivity measures and food value chain research
- Review of Climate-KIC systems innovation methodology and related research (Climate-KIC, 2023)

Appendix 4: Review on technologies and opportunities to improve energy efficiency in the food value chain

A4.1 Improved energy management and efficiency measures

Energy management and efficiency measures are very crucial to improve energy productivity in the value chain, not only by offering several benefits to businesses implementing them, but in turn also extending some benefits to other stakeholders in the value chain (Worrell, 2003). However, energy efficiency does not currently seem to represent a primary concern for many businesses. Moreover, it is not deemed to be a major factor in the costs of production in many value chains because its full benefits are not recognised, as discussed in the main report.

In many cases the lifecycle energy impact of production decisions occurs outside the boundaries of businesses making these decisions: referred to as Scope 3 emissions. Nonetheless, energy productivity, when applied to industry, starts with understanding the value of what is being produced, and then considers whether there are other means to realise that value. As a result, multiple benefits are more suited to process improvements and refinements of existing systems, while energy productivity also includes the prospects of more profound changes such as disruptions and demand diversions and market transformations (Trianni et al., 2022).

In the food and beverage manufacturing industry, energy efficiency solutions can be divided into three categories: general efficiency, energy-efficient technologies, and efficiency accelerator products. General efficiency measures include better energy management and maintenance practices, such as avoiding unnecessary equipment use, optimising production schedules, and properly maintaining and sizing controls, motors, and steam systems. Energy-efficient technologies include the use of advanced refrigeration systems, and advanced insulation on equipment and pipes. Accelerator technologies include innovative technologies and practices such as the use of microwave drying and heating, advanced oven technologies, and mechanical and thermal vapour recompression techniques (Sovacool, 2021).

The potential energy savings from these efficiency measures can be significant, such as reducing energy consumption for refrigeration by 16-27% through the use of refrigerant blends, and reducing energy consumption for some processes by 50-90% through the use of better-designed pumps and heating, ventilation and air conditioning systems (Sheppard & Rahimifard, 2019). Even simple practices such as installing pump controls or turning off refrigerators when temperatures drop below freezing can save 10-30% of required energy (Cantore, 2017).

A4.2 Implementation of renewable energy solutions

According to the International Renewable Energy Agency (IRENA), the food and tobacco sector has the second-highest potential for adopting renewable sources of electricity and heat, after the pulp and paper sector. They estimate that 60% of existing heat demands within this sector can be met by renewable energy, particularly for low to medium temperature applications (IRENA, 2015).

Distributed and modular electric processing technologies and renewable energy and utilisation of rural and regional renewable energy resources opens up potential to 're-energise' rural and regional economies and disrupt traditional supply chains. There are several options in renewable energy diffusion that can be used in the food and beverage sector. The choice of a specific option will depend on the specific energy needs of the facility, the availability of renewable energy sources in the location at suitable times, and the economic feasibility of the option. However, the most promising options for renewable energy in food value chain include the integration of biomass energy, solar thermal heating, and heat pumps powered by decarbonisation technologies (Sovacool, 2021). Among these technologies, the usage of heat pumps can improve the efficiency of conventional air dryers and function as a dehumidifier. Similarly, replacing coal or natural gas with biomass, such as waste biomass or biogas from anaerobic digestion, can lead to significant emissions reductions. Additionally, switching to electric heating equipment powered by renewable energy can also result in substantial emissions reductions (Kanchiralla, 2021). Anaerobic digestion and the use of biogas digesters are considered important options for the dairy industry due to the presence of livestock and resulting manure, as well as high demand for energy at times when solar resources are limited. Solar energy can also be utilised for agriculture, including drip irrigation systems. Energy efficiency and productivity, demand management and energy storage measures can dramatically improve the economics of renewable energy in the food value chain (Nikkah & Van haute, 2020).

A4.3 Digitalisation (Industry 4.0) solutions

Industry 4.0 solutions can play an important role in decarbonising the food value chain. Some of the ways that these technologies can help include:

- Smart manufacturing and processing: Industry 4.0 technologies such as IoT, and advanced process control systems can be used to monitor and optimise energy usage throughout the food value chain. Similarly, advanced sensors can be used to monitor and control temperature, humidity, and other parameters in food storage and processing facilities, reducing energy consumption and waste. On the other hand, machine learning algorithms can be used to predict equipment failures and schedule maintenance.
- Digitalisation and provenance tracking can identify costs and benefits and allocate money in ways that recognise the roles, costs and benefits of each value chain participant. This is important for circular economy and Scope 3 emission accounting as well as energy productivity (Trianni et al., 2022).
- Reduced Food Waste: Industry 4.0 technologies can also be used to reduce food waste by improving supply chain visibility and logistics. For example, RFID tags and sensors can be used to track the location and condition of food products, allowing for more efficient and targeted distribution and quality management.
- Sustainable Agriculture: Industry 4.0 technologies can also be used to improve the sustainability of agriculture. For example, precision agriculture techniques such as drones and sensors can be used to monitor crop health and soil conditions, allowing for more efficient use of water and fertilisers, reducing the environmental impact of farming.
- Carbon footprint tracking: Industry 4.0 technologies can be used to track the carbon footprint of food products throughout the value chain, allowing companies to identify areas where they can reduce emissions and improve sustainability.

A4.4 Eco-design

Eco-design is a method that takes into account the environmental impact of a product throughout its entire lifespan, from sourcing raw materials to disposal or recycling. It aims to decrease the use of resources and the related carbon emissions throughout the value chain (Braungart et al., 2007). For instance, by designing products that use less energy, water, or raw materials, the environmental impact of the food value chain can be lessened. Additionally, eco-design can also promote the use of sustainable materials throughout the food value chain by designing products that use more environmentally friendly materials, such as recycled materials or bioplastics, which helps to decrease the environmental impact of the food value chain (Plouffe et al., 2011). Furthermore, it can be used to design products with end-of-life in mind, making it easier and more cost-effective to recycle or dispose of products at the end of their life. This can decrease the environmental impact of the food value chain by lowering the amount of waste sent to landfills.

A4.5 Product labelling: energy, carbon, date and other criteria

Product labelling can be a valuable tool for promoting sustainability and reducing the carbon footprint of the food value chain. For example, by providing consumers with information about the energy consumption of products, it can empower them to make more informed purchasing decisions. This increased awareness can drive demand for more energy-efficient products and motivate manufacturers to improve the energy efficiency of their products. Moreover, labels can be used as a benchmarking tool, enabling manufacturers to compare the performance of their products to that of competitors (Haris & Casey-McCabe, 1996).

A4.6 Circular economy approach

By promoting the reduction, reuse, and recycling of resources and materials, the circular economy approach can optimise the use of energy, minimise waste, and reduce environmental impacts. This can lead to increased energy productivity, cost savings, and other benefits for stakeholders in the food value chain (Sovacool, 2021). Additionally, the circular economy approach can encourage innovation and collaboration among stakeholders, leading to the development of new and more efficient technologies and practices that improve energy productivity.

A4.7 Innovative business models

Business models can play a key role in helping to improve energy productivity in the product's value chain and adopt more sustainable practices. They can be designed to leverage the initiatives of energy efficient technology adoption (Trianni et al., 2022). It's worth noting that these business models are not typically used alone, but rather in combination with other models, such as pay-per-use models or service-based models. e.g. the X-as-a-service suite and pay-per-X business models. There is also the possibility to observe redundancy in the patterns with closely linked characteristics.

In addition, it is worthwhile mentioning that, whilst these business models hold great market potential, some are yet to secure a strong foothold in extant markets. The flexibility of the servitisation approach, for example, has often been met with challenges in terms of the ambiguity customers may experience whilst trying to decipher the value proposition of some service offerings. However, the opportunities associated with their adoption hold the potential to also be of significant benefit for participating stakeholders.

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