HLPE REPORT 8

Food losses and waste in the context of sustainable food systems

A report by

The High Level Panel of Experts on Food Security and Nutrition

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CFS Committee on World Food Security

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HLPE Reports series

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FOREWORD

Although accurate estimates of losses and waste in the food system are unavailable, the best evidence to date indicates that globally around one-third of the food produced is lost or wasted along the food chain, from production to consumption.

This policy-oriented report from the High Level Panel of Experts on Food Security and Nutrition (HLPE) presents a synthesis of existing evidence about the causes of food losses and waste and suggests action to reduce them in order to improve food and nutrition security and the sustainability of food systems. The aim of this report, given the diversity of contexts, is to help all concerned actors to reduce food losses and waste by identifying the causes and potential solutions that may be implemented, alone or in a coordinated way, by the relevant actors in the food system, including the public and private sectors, civil society, individual producers, wholesalers, retailers and consumers. Successful reduction of food losses and waste will save resources and has the potential to improve food security and nutrition, goals shared with the Zero Hunger Challenge and the post-2015 sustainable development agenda.

The HLPE was created in 2010 to provide the United Nations' Committee on World Food Security (CFS) with evidence-based and policy-oriented analysis to underpin policy debates and policy formulation. While specific policy interventions should be based on context-specific understanding, HLPE reports provide all stakeholders with evidence relevant to the diversity of contexts, and recommendations expected to be useful to guide context-specific policy interventions.

The HLPE works on topics identified by the CFS. This is the eighth HLPE report to date. Past reports have covered seven topics related to food security and nutrition, considered by the CFS for their importance in relation to world policy agenda, including price volatility, land tenure and international investments in agriculture, climate change, social protection, biofuels, investment in smallholder agriculture and, most recently, sustainable fisheries and aquaculture. Work is underway for an HLPE report on water and food security to feed into CFS's policy debates in 2015.

The Steering Committee of the HLPE consists of 15 members including a Chair and a Vice-Chair. In addition, the HLPE includes a wide range of researchers who work on the various reports. A large number of experts, including many peer reviewers, contribute to our work. The tenure of the first Steering Committee ended in the fall of 2013. I praise the wisdom of the CFS for having reappointed four of the outgoing members, including the Vice-Chair, Ms. Maryam Rahmanian, to provide the necessary continuity.

It was an honour and a pleasure to be elected by the Steering Committee members to succeed M. S. Swaminathan as chair of the Steering Committee. I want to take this opportunity to express my great appreciation to M. S. Swaminathan who, before leaving his seat, marked the first 1000 days of the HLPE with his vision and energy.

I would like also to pay my tribute to all the members of the first HLPE Steering Committee, as well as to the many individuals who contributed to the high quality of the work by HLPE. I also wish to thank my colleagues currently serving on the Steering Committee for their dedication, hard work and the successful contributions they have made. In particular, I would like to highlight the exceptional commitment and the tremendous contributions made by the HLPE Coordinator, Vincent Gitz, and his colleagues at the HLPE secretariat.

I am grateful to a large number of experts who contributed to this report including the members of the first and the current HLPE Steering Committees, in particular Renato Maluf who convened the Steering Committee's oversight for this report, and to the Project Team leader V. Prakash (India) and the Project Team members Toine Timmermans (Netherlands), Walter Belik (Brazil), Jikun Huang (China) and Jane Ambuko (Kenya). The report also benefited greatly from comments and suggestions by the external peer reviewers and a large number of experts and institutions who commented extensively both on the terms of reference and on a first draft of the report. Last but not least, I would like to thank the resource partners who support, in a totally independent way, the work of the HLPE.

Per Pinstrup-Andersen

Chair, Steering Committee of the HLPE, 21 May 2014

SUMMARY AND RECOMMENDATIONS

The issue of global food losses and waste has recently received much attention and has been given high visibility. According to FAO, almost one-third of food produced for human consumption – approximately 1.3 billion tonnes per year – is either lost or wasted globally: their reduction is now presented as essential to improve food security and to reduce the environmental footprint of food systems.

In this context, the Committee on World Food Security (CFS), in its Thirty-ninth Session (October 2012) requested the High Level Panel of Experts on Food Security and Nutrition (HLPE) to undertake a study on "Food losses and waste in the context of sustainable food systems" to be presented to the CFS Plenary in 2014.

The very extent of food losses and waste invites to consider them not as an accident but as an integral part of food systems. Food losses and waste are consequences of the way food systems function, technically, culturally and economically. This report analyses food losses and waste in a triple perspective: a systemic perspective, a sustainability perspective, including the environmental, social and economic dimensions of sustainability, and a food security and nutrition perspective, looking at how food losses and waste relate to the various dimensions of food security and nutrition.

Main findings

Scope and extent of food losses and waste

1. Food losses and waste have been approached by two different angles: either from a waste perspective, with the associated environmental concerns, or from a food perspective, with the associated food security concerns. This duality of approaches has often led to confusions on the definition and scope of food losses and waste, contributing to unreliability and lack of clarity of data.
2. This report adopts a food security and nutrition lens and defines *food losses and waste* (FLW) as "*a decrease, at all stages of the food chain from harvest to consumption, in mass, of food that was originally intended for human consumption, regardless of the cause*". For the purpose of terminology, the report makes the distinction between *food losses*, occurring before consumption level regardless of the cause, and *food waste*, occurring at consumption level regardless of the cause. It further proposes to define *food quality loss or waste* (FQLW) which refers to the decrease of a quality attribute of food (nutrition, aspect, etc.), linked to the degradation of the product, at all stages of the food chain from harvest to consumption.
3. There are numerous studies on FLW with diverse scopes and methodologies, making them difficult to compare. At the global level, recent studies use the data compiled for the FAO report published in 2011, which estimated global FLW at one third of food produced for human consumption in mass (equivalent to 1.3 billion tonnes per year), or one quarter as measured in calories.
4. The distribution of FLW along the food chain varies greatly by region and product. In middle and high-income countries, most of the FLW occur at distribution and consumption; in low income countries, FLW are concentrated at production and post-harvest. Per-capita FLW peaks at 280–300 kg/cap/year in Europe and North America and amounts to 120–170 kg/cap/year in sub-Saharan Africa and South/Southeast Asia.
5. Different definitions, different metrics, different measurement protocols and the lack of standards for data collection adapted to different countries and products, makes it difficult – and sometimes impossible – to compare studies, systems and countries. There is also no agreed method to evaluate the quality of data, method and numbers produced. This situation is a huge barrier to understanding and identifying the causes and extent of FLW, the potential for solutions, the priorities for action and the monitoring of progress in reducing FLW. This is why there are currently strong calls for the development of global protocols to measure FLW, taking into account the large number of variables and country specificities, towards a harmonization of definitions and measurement methods, with a view to improve the reliability, comparability and transparency of data.

Impacts of FLW on food security and nutrition and on the sustainability of food systems

6. FLW impact both food security and nutrition and the sustainability of food systems. This report looks at FLW in the context of sustainable food systems, and adopts the following definitions, as adapted from a range of other definitions.

7. *A food system* gathers all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes.

8. *A sustainable food system (SFS)* is a food system that delivers food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised.

9. FLW impact food security and nutrition by three main ways. First, a reduction of global and local availability of food. Second, a negative impact on food access, for those involved in harvest and post-harvest operations and who face FLW-related economic and income losses, and for consumers due to the contribution of FLW to tightening the food market and raising prices of food. Third, a longer-term effect on food security results from the unsustainable use of natural resources on which the future production of food depends.

10. Two additional relationships between FLW and food security and nutrition are less explored in the literature. One relates to quality and nutrient losses all along food chains, including at consumer level, which negatively impact nutrition. The second relates to the characteristics a food system should have to assure the "stability" dimension of food security, especially given the "variable" nature of food production and consumption. FLW may be indissociable from the need for appropriate "buffering" mechanisms – and some degree of redundancies – to handle the sometimes very high variability of production and consumption in time and in space.

11. FLW also impact the sustainability of food systems in all the three dimensions: economic, social and environmental. They induce economic losses and reduce return on investments. They impede development and hinder social progress. They have an important impact on the environment both from the superfluous use of resources used to produce the food lost and wasted, and from the local and global environmental impacts of putting food waste at disposal in landfills, including the emissions of methane, a potent greenhouse gas.

Organizing the description of causes of food losses and waste: micro, meso and macro causes

12. Identification of causes of FLW is primordial to identification of solutions to reduce FLW, and priorities for action. FLW can result from a very wide range of antecedents, ranging from biological, microbial, chemical, biochemical, mechanical, physical, physiological, technological, logistical, organizational, to psychological and behavioural causes – including those induced by marketing, etc. The importance of these antecedents vary greatly according to the produce and the context, and the stage of the food chain considered. Some studies have identified as much as several hundreds of different individual causes of FLW.

13. Identifying the causes of FLW requires an integrated perspective along the food chain, and to consider any action at one specific stage not in isolation but as part of a whole. Just as in a conveyor belt, actions at one stage of the food chain can affect the whole chain. It is important not to confuse "where" a specific loss or waste is occurring, with its "cause". FLW happening at one stage of the food chain can have their cause at another stage. For instance, some part of FLW happening at retail and consumption stages can be traced back to causes at harvest or even pre-harvest stages. Lack of care in the manipulation of fruits during harvest and packaging, which in turn can be related to poor work conditions, can reduce their shelf-life and cause retail-level loss or consumer waste. Conversely, fruits can be left to rot in the field because of a retailer's decision to lower its buying price or interrupt a contract.

14. Causes are often interrelated: rarely a loss or a waste appearing at one stage of the chain, for a particular reason, is solely dependent on one specific cause.

15. This report proposes to disentangle the complexity and diversity of causes in organizing their description amongst three different levels

i. First, “micro-level” causes of FLW. These are the causes of FLW, at each particular stage of the food chain where FLW occurs, from production to consumption, that result from actions or non-actions of individual actors *of the same stage*, in response (or not) to external factors.

ii. Second, “meso-level” causes of FLW. These include secondary causes or structural causes of FLW. A meso-level cause can be found at another stage of the chain as to where FLW happen, or result from how different actors are organized together, of relationships along the food chain, of the state of infrastructures, etc. Meso-level causes can contribute to the existence of micro-level causes.

iii. Third, “macro-level” causes of FLW. This higher level accounts for how food losses and waste can be explained by more systemic issues, such as a malfunctioning food system, the lack of institutional or policy conditions to facilitate the coordination of actors (including securing contractual relations), to enable investments and the adoption of good practices. Systemic causes are those that favour the emergence of all the other causes of FLW, including meso and micro causes. In the end, they are a major reason for the global extent of FLW.

Micro level causes of food losses and waste along food chains

16. Micro-level causes can be found all along the food chain, and are the direct, immediate reasons for FLW taking place at a certain point of the chain, resulting from actions (or non-action) at the same point of the chain, on how individual actors deal with various factors potentially leading to FLW.

17. Poor harvest scheduling and timing, and rough, careless handling of the produce, are both major contributors to FLW.

18. All along the food chain, inadequate or lack of storage conditions and, for perishable products, poor temperature management are key factors leading to FLW.

19. Transport can be a major cause of FLW: by introducing a time span between production and consumption, of particular importance for fresh products and by bringing additional risks of mechanical and heat injury. Time spent because of transport can also lead to decrease of nutritional contents.

20. Conditions within the retail outlet (temperature, relative humidity, lighting, gas composition, etc.) and handling practices have an effect on quality, shelf-life and acceptability of the product.

21. FLW at consumer stage, at household level but also in catering and other food services, are particularly important in developed countries. They are mainly driven by behavioural causes, including habits of food buying, preparation and consumption, as well as time planning and coordination. They are influenced by marketing techniques which encourage consumers to buy more than they need.

Meso and macro-level causes of FLW

22. Very often causes of FLW are found at “higher” meso- and macro-levels, which lead to FLW (and their micro-causes) happening at various stage of the chain.

23. At meso-level, the lack of equipment and/or of good practices, inadequate organization, coordination and communication between food chain actors (e.g. transformation that renders the product useless at a later stage of the chain, etc.), inadequate infrastructure, maladapted economic conditions along the food chain (product unmarketable, etc.) are major causes of FLW at various parts of the food chain. More macro-level, systemic causes include the absence of a good, enabling environment to support coordination between actors, investment and improvement of practices.

24. Pre-harvest conditions and actions in the field can indirectly lead to losses at later stages in the chain, as production and agronomic practices influence quality at harvest, suitability for transport and shipping, storage stability and shelf-life after harvest.

25. The retailers influence the activities of supply chains by dictating the quality of the produce to be supplied and displayed in their outlets. Quality standards (as to shape, size, weight) imposed by the processors, retailers or target markets can lead to produce not meeting them remaining un-harvested.

26. Inadequate information and bad anticipation of market conditions (level of demand, prices) can also lead to produce remaining unharvested.

27. In many low-income countries, there is considerable food loss due to lack of storage capacity and poor storage conditions as well as lack of capacity to transport the produce to processing plants or markets immediately after harvesting. There are also too few wholesale, supermarket and retail facilities providing suitable storage and sales conditions for food products. Wholesale and retail markets in developing countries are often small, overcrowded, unsanitary and lack cooling equipment.

28. Poor transportation infrastructure is another important meso-cause of FLW.

29. Even with adequate equipment, lack of implementation of good practices all along the food chain is a major cause of food losses and waste.

30. Confusion arising from the existence and poor understanding of different food date labels are a major, indirect cause of FLW at the retail and consumer levels. Consumers tend to assume that these dates are linked to food safety when in reality they are more often based on food quality (which will deteriorate over time without necessarily becoming a health hazard). Many kinds of date labels coexist, some of them not intended to inform consumers but rather to help retailers manage their stock. Other date labels are directed to consumers, but their purpose can be very different whether the indicated date is related to food safety rules, or related to marketing strategies to protect consumers' experience of a product in the view to safeguard its reputation, often with a huge food safety margin. Consumers get lost in this multitude of date labels. Furthermore, date labeling is a major cause of FLW and economic loss at the retail level as retailers often anticipate dates to preserve their good image.

31. At macro-level, the ability of the actors of the food chain to reduce FLW depend on the surrounding policies and regulatory frameworks. Many regulations affect FLW, including policies that control the use of surplus food for humans or for animal feed; policies or bans on fish discards; food hygiene regulations; food labelling and packaging regulations; waste regulations and policies. Other regulations might not have a direct impact on FLW, but on the potential to use them as feed or energy.

Micro solutions to reduce food losses and waste

32. The identification of broad categories and levels of causes enables to design pathways for all stakeholders to identify and implement solutions to reduce FLW.

33. The review of "micro" causes of FLW at each stage of food chains leads to the identification of potential solutions and of actors to implement them. At each stage of the food chain, some solutions can be implemented by single actors to address specific causes of losses and waste.

34. Micro-level solutions at harvest and post-harvest stages involve improved practices, adoption of technical innovations, investments, or a combination of these. When appropriately applied, good agricultural practices and good veterinary practices at the primary stage of production as well as good manufacturing practices and good hygienic practices during food processing can protect food from contamination or damage. A key intervention all along food chains is to improve storage conditions. Various solutions have been already successfully implemented in many places.

35. Modifying consumers' behaviour is also important. It involves direct communication and awareness raising on the importance of reducing food waste. Stressing the civic responsibility for reducing FLW is important. Consumers may also need technical options, such as better, smart packaging adapted to different conditions of use, or the promotion of the "doggy bag" practice in restaurants. It also requires the support and cooperation of the food industry and retailing, for instance to improve the clarity of food date labelling and to provide advice on food storage, or to ensure that an appropriate range of pack or portion sizes is available to meet the needs of different households

Meso-level solutions

36. Micro-level solutions can be supported and enhanced by actions at meso-level, often involving several actors altogether, public and private.

37. They often require investments, both public and private. This is particularly the case when the main solutions reside in improvement of logistics. For perishable products, management of temperature and absence of delays are two vital issues that require investments in infrastructures (energy for cold chains, roads for transportation). Innovation and adaptation of technical solutions to local conditions are essential for success. Cold chain management in perishable foods supply chains offers a very good example of potential solutions and what is needed to implement them in locally adapted ways.

38. For many products, particularly for perishable ones, transformation can be a way to reduce FLW and improve resistance to transport and storage, and increase shelf life. Investment in food processing infrastructure, including packaging, can be seen as a huge opportunity to contribute to improved situations of food security, especially in sustainable ways to fulfil the growing demands of metropolitan areas.

39. Capacity development in the form of education, training and extension services for farmers and all actors across the food chain is a key tool for reducing food losses and waste.

40. There are initiatives from government and development partners in developing countries to improve the livelihoods of women farmers through value addition and marketing of perishables food crops such as fruits and vegetables. These initiatives have two-pronged benefits – economic empowerment of rural women and reduction of post-harvest losses in the perishable commodities.

41. The increasing inclusion in annual corporate businesses reports of a section detailing the environmental and social impacts of their activities could lead to more sustainable food systems and less FLW. Businesses can commit and report (i) on monitoring of food losses and waste in their activities, (ii) on reducing food losses and waste in their activities, (iii) support activities which lead to reduction of FLW, with their suppliers, at consumer level or elsewhere.

42. The standardization of the products offered to consumers is a major cause of FLW in modern retailing systems. In traditional systems products gradually lose their economic and exchange value along with their quality, as defined by the FLWQ concept. They are generally still sold or exchanged, but at gradually lower prices. In modern, standardized systems, products are rather defined as marketable or not. They "suddenly" lose all their economic value when they are no more of the minimum quality considered as marketable – which is often not linked to their edibility – as illustrated by the confusion on date labelling. Alternative distribution systems such as food banks preserve them an edible value.

Macro-level (systemic) solutions

43. Solutions at micro- or meso-level can be enabled, supported and enhanced by action at macro-level. Some solutions can only be implemented if they are accompanied by action at "macro" level. This includes specific policies against FLW or considering FLW in other sets of policies. As mentioned above, reducing FLW often involves improving infrastructures, particularly transport, energy and market facilities. This requires government action, with often involvement of local authorities and also of the private sector. Decisions and policies would deserve to be based on sound cost-benefit analysis, so as for example to ensure that the right incentives or corrective measures are put in place.

44. Many of the causes of FLW – and therefore the appropriate solutions – are due to behavioural or economic choices, which seem rational at one stage of the chain, but may lead to FLW when the rest of the food chain is considered. For example, the decision of a farmer to plant a larger field at the expense of not necessarily harvesting the whole of it depending on market conditions; the decision of food chain agents to overbuy food with respect to potential sales and their variability; supermarkets needing to show a situation of abundance of products to attract clients, etc. Tackling these causes of food losses and waste will imply addressing their underlying economic and behavioural drivers, understanding their reasons, and finding a "substitution" to the different "functions" that these actions (which may end up in creating FLW) "ensure" for the different actors.

45. Solutions to be implemented at meso and macro level generally require concerted and collective action and measures. Prior identification of potential winners and losers across the whole food system, and the design of appropriate incentive or compensation mechanisms, is key to the success of implementation. This includes in particular assessing whether the poor producers and consumers gain from FLW reduction. It should also consider how the "FLW-to-be-reduced" was originally used (e.g. was it used as feed for animals or thrown away?). To avoid unintended

consequences of FLW reduction strategies, policy makers and stakeholders should consider all the impacts of the proposed changes.

A growing set of initiatives towards coordinated actions to tackle FLW

46. There are a growing number of initiatives around the world that focus on reducing FLW, at national, regional and local levels. They have all as common denominator the perspective of gathering public and private actors, in a multistakeholder setting, often with a significant engagement of the private sector.

47. Some governments have started to define specific targets for FLW reduction. However few governments have put in place specific policies to reduce FLW, less even with a systemic approach and integrated programmes. To date, main drivers for FLW targets are generally found outside the perimeter of food policies, such as in waste management policies leading to reducing the volume of waste, including packaging waste, and in resource use efficiency policies leading to optimize, in analogy to the energy sector, the amount of inputs and resources (including raw food products) in production and consumption.

48. Reducing food losses and waste requires identifying causes and selecting potential solutions adapted to local and product specificities. It includes evaluating potential costs and benefits of various options for different actors along the chains. The implementation of the selected solutions generally requires the support or involvement of other actors, inside the food chain or at broader levels. This often calls for coordinated action of multiple stakeholders. It also calls for actions at policy level, to improve policies having an impact on FLW, or to build specific FLW reduction policies.

Recommendations

Food losses and waste (FLW) impact both food security and nutrition and the sustainability of food systems, in their capacity to ensure good quality and adequate food for this generation and future generations. It calls for all stakeholders – States, international organizations, private sector and civil society – to recognize food security and nutrition as a central dimension of sustainable food systems and to address collectively FLW to improve the sustainability of food systems and to contribute to food security and nutrition.

According to FAO, nearly one-third of food produced for human consumption – approximately 1.3 billion tonnes per year – is either lost or wasted globally. The HLPE makes the following recommendations as a way of making serious progress to reduce this figure.

The HLPE recommends that States and international organizations better integrate food chains and food systems perspectives in any food security and nutrition strategy or action. Reduction of FLW should be systematically considered and assessed as a potential means to improve agricultural and food systems efficiency and sustainability towards improved food security and nutrition. Direct and indirect causes of FLW in a given system should be analysed to identify hotspots where it would be most efficient to act.

The HLPE recommends undertaking four parallel mutually supportive tracks, in an inclusive and participatory manner:

1. Improve data collection and knowledge sharing on FLW.
2. Develop effective strategies to reduce FLW, at the appropriate levels.
3. Take effective steps to reduce FLW.
4. Improve coordination of policies and strategies in order to reduce FLW.

1) <u>Improve data collection and knowledge sharing on FLW</u>

All stakeholders should

1a) Agree on a shared understanding, definition and scope for FLW.

1b) Improve the collection, transparency and sharing of data, experiences and good practices on FLW at all stages of food chains.

FAO should

1c) Consider developing common protocols and methodologies to measure FLW and analyse their causes. This should be done through an inclusive and participatory process, taking into account product, country and all stakeholders' specificities and building upon FAO's experience.

1d) Invite all stakeholders, international organizations, governments, private sector and civil society to collect and share data on FLW in a coherent and transparent manner at all stages of food chains.

2) Develop effective strategies to reduce FLW, at the appropriate levels

States should

2a) Convene an inclusive process to identify hotspots, causes of losses and waste at different levels (see Appendix 1), potential solutions (see Appendix 2) and levels of intervention. This requires identifying the actors who will directly implement solutions, individually or collectively, identify the costs they will bear, as well as potential benefits and beneficiaries. It also requires identifying constraints (including systemic constraints) and how they would be addressed (infrastructure, technologies, changes of organization in the food chain/system, capacity building, policies and institutions).

2b) Determine a plan of action in a manner that includes all stakeholders.

FAO should

2c) Support these national processes in collaboration with partners to devise methodological guidance adapted to countries' specificities, and needs and priorities of various actors.

3) Take effective steps to reduce FLW

States should

3a) Invest in infrastructure and public goods to reduce FLW and to ensure sustainable food systems such as storage and processing facilities, reliable energy supply, transport, appropriate technologies, improved access and connection of food producers and consumers to markets.

3b) Implement an adequate framework including regulation, incentives and facilitation so that the private sector (e.g. wholesaler, retailer, catering and other food services) and consumers take robust measures to tackle unsustainable consumption patterns. This framework should also ensure that the private sector better incorporates negative externalities of their activities such as damage to natural resources.

3c) Take measures to support smallholders to reduce the FLW by organizing themselves in ways that yield economies of scale and allow them to move towards high value activities in the food supply chain.

3d) Create an enabling environment for the reduction of FLW including by encouraging sustainable patterns of consumption among the population, as well as food and non-food investments promoting food security.

3e) Encourage sector-based audits of FLW.

3f) Reform public food procurement policies to reduce and minimize FLW while ensuring food safety.

3g) Design and introduce procedures to ensure higher corporate accountability standards for FLW, and monitor reductions in FLW in the food processing and retailing sectors.

States and other stakeholders, including international organizations, private sector and civil society should

3h) Carry out training and capacity building to strengthen the coordinated use of appropriate technologies.

3i) Promote experimentation and the exchange of good practices regarding FLW.

3j) Recognize the plurality of food systems in their diverse contributions to FLW and various potentials to reduce them.

3k) Enable and support multistakeholder initiatives to improve governance along food chains and organize collective understanding and action to reduce FLW.

3l) Invest in research and development to minimize FLW.

3m) Improve the dissemination of accurate information and advice to consumers to minimize FLW.

3n) Encourage civic engagement of all actors, including consumers, to act concretely to reduce FLW in particular through public campaigns, education of youth and children.

Private sector should

3o) Develop and implement corporate responsibility policies to diminish FLW including by collecting and sharing data on FLW and ensuring that the costs and benefits of FLW reduction are appropriately shared.

3p) Get involved with collective actions and initiatives for reducing FLW, including by mobilizing companies to change their practices in order to reduce FLW in households.

3q) Reform supermarket and food retailer practices such as product standards used to accept or reject farmers produce (e.g. size and shape of foods as well as cosmetic standards for fruit, vegetables, livestock products). This can be done for example by introducing differentiated pricing to prevent economic and nutrition value losses.

National and International research and development organizations should

3r) Increase investment in technological innovations at post-harvest and consumption stages for effective reduction of FLW as well as for adding value to agricultural products in the whole food value chain, for example through the extension of shelf life while protecting nutritional value.

4) Improve coordination of policies and strategies in order to reduce FLW

States should

4a) Integrate FLW concerns and solutions, and a food chain approach, in agricultural and food policies and development programs, as well as in other policies which could impact FLW.

4b) Strengthen the coherence of policies across sectors and objectives (e.g. sustainable food consumption, dietary guidelines, food safety, energy, and waste).

4c) Set targets and introduce enabling economic policies and incentives to reduce FLW, through a "food use-not-waste" hierarchy (i.e. prevention, reallocation of food for feed, recycle for energy through anaerobic digestion, recover for compost, disposal, and ultimately, if no other solution is available, in landfills).

4d) Support efforts for coherence, clarification and harmonization of the meaning and use of food dates labelling, at national as well as international level taking into account the principles of the *Codex Alimentarius*.

4e) Ensure a holistic food chain approach, with adequate research and extension services, including towards small transport, transformation and distribution enterprises.

4f) Support coordination of efforts through multistakeholder initiatives, such as the global "Save Food" initiative.

All Stakeholders should

4g) Improve communication, coordination, recognition of efforts needed/made at one stage to reduce FLW at another stage (downstream or upstream).

CFS should

4h) Consider convening an inclusive meeting to share successful experiences, challenges faced and lessons learned from FLW initiatives.

4i) Develop guidelines to assist governments in an assessment of their food systems with a view to reduce FLW.

4j) Raise awareness of the importance of reducing FLW and disseminate this HLPE report to international organizations and bodies.

INTRODUCTION

The issue of global food losses and waste (FLW) has recently received much attention and has been given high visibility. According to FAO (2011a), almost one-third of food produced for human consumption – approximately 1.3 billion tonnes per year – is either lost or wasted globally. The reduction of FLW is now presented as essential to improve food security (HLPE, 2011; FAO, 2012a,b) and to reduce the environmental footprint of food systems (HLPE, 2012; FAO, 2012a,b; UNEP, 2012a,b).

The attention given to the topic is driven by two main categories of concerns. First, a concern related to food insecurity and hunger: the extent of FLW while more than 800 million people still suffer from hunger seems to indicate that something is wrong, that food systems do not function as they should. This perception includes a moral dimension, with various estimates of the number of people who could be fed with what is lost, discarded or wasted – although there is no proven direct link between the incidence of global FLW and the extent of global food insecurity. Second, a concern related to the impact of FLW on natural resources and the environment, in a context of growing interrogations about the capacity of ecosystems and natural resources to sustain an increasing demand for food, estimated by FAO to reach +60 percent towards 2050, driven by population and income growth and changing consumption patterns (FAO, 2012a). In this perspective, FLW represents at the same time a waste of resources, as well as an environmental issue by itself, as for example food-related waste, as part of urban total waste, has a significant greenhouse gas (GHG) footprint.

At the origin of economic, environmental and social concerns, FLW tend to become a symbol of the inefficiency, unfairness and unsustainability of food systems. Reducing them seems a priority to improve the sustainability of food systems. The issue was prominent on the agenda towards the preparation of the Rio+20 Conference, which connected the reduction of food losses and waste to the issue of more sustainable food systems, linking sustainable consumption and production, recognizing that production is driven by consumption, and that the environmental impacts of food systems have to be assessed all along food chains. The Zero Hunger Challenge launched by the Secretary-General of the United Nations in Rio de Janeiro during the Conference integrates a zero-food-loss-and-waste challenge along with a 100 percent-sustainable-food-systems challenge.

The Committee on World Food Security (CFS), in its Thirty-ninth Session (October 2012) requested the High Level Panel of Experts on Food Security and Nutrition (HLPE) to undertake a study on “Food losses and waste in the context of sustainable food systems” to be presented to the CFS Plenary in 2014.

Efficient, well-managed and sustainable food systems (SFS) are essential to end hunger and malnutrition as well as to protect the environment and its long-term food production capacity. “*The key to better nutrition, and ultimately to ensuring each person’s right to food, lies in better food systems – smarter approaches, policies and investments encompassing the environment, people, institutions and processes by which agricultural products are produced, processed and brought to consumers in a sustainable manner*”, Secretary-General Ban Ki-moon said in his message for the World Food Day on 16 October 2013 (UN, 2013).

By requesting the HLPE to examine the issue of food losses and waste *in the context of sustainable food systems*, the CFS invited the HLPE to consider the very notion of sustainable food systems and the relationships between FLW and SFS, i.e. to investigate how the reduction of food losses and waste could improve the sustainability of food systems, as well as how unsustainable food systems contribute to food losses and waste. Central to this report is how sustainable food systems relate to food security and nutrition (FSN), as a condition to ensuring food and nutrition security for all, now and in the future.

This report aims at a better understanding of what FLW mean, their extent, the reasons behind, and the means to reduce them. It does so in a triple perspective: a systemic perspective; a sustainability perspective, including the environmental, social and economic dimensions of sustainability; and a food security and nutrition perspective, looking at how FLW relate to the various dimensions of FSN.

The very extent of FLW invites to consider them not as an accident but as an integral part of food systems. FLW are consequences of the way food systems function, technically, socially, culturally and economically. Therefore, one can only study FLW, their impacts, causes and potential ways to reduce them, by adopting an integrated and holistic view of food production, commercialization and consumption, mobilizing a vast array of disciplines, from the biology of food products and conservation technologies, to organization and economics of food chains and markets as well as consumer behaviour. The task is made all the more difficult by considerable gaps in data and knowledge. A wide diversity of products, food chains and systems need to be accounted for, including their social and cultural dimensions as well as for the considerable changes under way.

To address the above, the report adopts the following approach.

Chapter 1 clarifies the definitions and approaches used in the report to consider FLW, and summarizes available data on the extent of FLW, recognizing that they are very much dependent on the specific conditions and local situations in a given country. It proposes a definition of SFS and analyses the impacts of FLW on the sustainability of food systems and on food security.

Chapter 2 reviews the range of causes of FLW, along food chains, production, storage and processing choices, patterns and technologies, infrastructure and capacity, marketing chains and channels for distribution, consumer purchasing, and food-use practices, etc. It aims to identify links between different levels of causes: micro, meso (structural) and macro (systemic) causes.

Chapter 3 proposes an organization of the solutions to reduce FLW to address the hierarchy of causes identified in Chapter 2. In doing so, the report tries to sort out the potential roles for the various actors intervening in/on food systems: producers, the private sector, consumers, social actors and governments.

The report is deliberately oriented towards action. It provides practical elements for actors to design their own solutions. It includes numerous examples, as well as two appendixes that can be of use to stimulate reflexion and action. Given all the analysis, and the elements presented in the first three chapters, Chapter 4 proposes a “way forward” to build strategies to reduce FLW that can be applied in diverse contexts with a perspective towards sustainable food systems providing sustainable food security and nutrition for all. Recommendations to different categories of actors are provided, which aim to sustain the rolling-out of the way forward, applicable to a diversity of contexts and situations.

1 FOOD LOSSES AND WASTE AND SUSTAINABLE FOOD SYSTEMS: DEFINITION, EXTENT AND IMPACTS

Numerous reports (e.g. Stuart, 2009; Foresight, 2011; FAO, 2011a; Lipinski *et al.,* 2013) have underlined the significance of food losses and waste (FLW) and the need to reduce them to improve food security and sustainability of food systems.

This chapter analyses the relations between the triptych "food losses and waste", "sustainable food systems" and "food security and nutrition".

It starts by defining food losses and waste and considers the way to measure them and their extent (Section 1.1). It presents the notion of sustainable food systems (Section 1.2). It finally explores how food losses and waste impact the sustainability of food systems as well as their capacity to ensure food security (Section 1.3).

1.1 What are FLW along food chains and how to measure them?

1.1.1 FLW concepts and definitions

What are FLW? Trying to define FLW and their scope, one is immediately confronted with two competing approaches, reflecting fundamentally different perspectives, underlying objectives and policy concerns. One approach focuses on waste, and for it FLW are *the part of waste that is food or related to food, including non-edible parts*. The other approach, retained in this report, focuses on food, and for it FLW are *the edible part of food that is lost or wasted*. A first distinction is therefore whether the approach to FLW is focused on waste or focused on food:

- The *waste-focused* approach derives from the concern of diminishing waste of all kinds, and reducing negative impacts and costs of the treatment of waste, mainly non-food but including food – and including non-edible parts of produce. It often reflects local environmental impact considerations, calling to consider "what happens with the waste", either as feed, recycled, for energy production, as compost to return nutrients to the soil, incineration or landfill.
- The *food-focused* approach considers as a starting point food[1] and parts of food *that are edible and intended for human consumption*, but lost or discarded at some point in the food chain. This leads to introduce, at the beginning of the chain, the cultural dimension of "*edibility*" (as parts of food that are originally considered "not edible" will not be accounted as lost or wasted) and, at the end of the chain, the food safety dimension of *"edibility*" (as food that was originally edible but *becomes* non-edible for food-safety reasons needs to be discarded, leading to food loss and waste). It invites considering improvement of the functioning of the food system, with a food chain perspective.

Another source of confusion is the use of diverse terms (Schneider, 2013) with diverse scopes and inconsistent use between authors. The literature often uses a distinction between food losses and food waste (FAO, 2011a; Parfitt, Barthel and Macnaughton, 2010). However, there is not a consistent practice in the literature on the exact scope of what is "food loss" and what is "food waste":

- For a first category of authors, the distinction between food loss and food waste is based on the stage of the food chain at which, physically, the loss or waste of food physically happens. In this category, food *losses* happen at the earlier stage of food chains, often also denominated post-harvest losses, and food *waste* happens at the later stages, towards the consumer, placing the boundary either at retail or at consumer level.
- A second category of authors uses a different approach to this distinction, linking it not to the stages of the food chain where a loss or waste physically occurs, but to the *nature or origin of the cause* of loss or waste, whether its cause is "behavioural" (waste) or not (loss); "voluntary" (waste) or not (loss); the result of an explicit choice (waste) or not (loss), etc. But such approaches raise the difficult question of determining whether and to what extent a particular discard of food is "behavioural", "voluntary" or the "result of a choice", given the different and

[1] "Food means any substance, whether processed, semi-processed or raw, which is intended for human consumption, and includes drink, chewing gum and any substance that has been used in the manufacture, preparation or treatment of "food" but does not include cosmetics or tobacco or substances used only as drugs" (FAO/WHO, 2013).

often very subjective perceptions of what these terms mean in different contexts, including different economic or moral meanings of the degree of real free will to come to discard food. It also tends to undervalue technical, organizational, economic and social constraints, which can predispose what is really behavioural, voluntary or the result of a choice, versus what is not.

- A third category of authors[2] uses "*food waste*" or "*food wastage*" as a generic term for "*food losses and waste*", which has the limitation that often some of this "waste" is in fact, under other approaches, a "loss". This gets further confusing when authors expand the scope to all "food-related" waste, which includes non-edible parts.[3]

This difficult discussion on the terminology is further dependent on the meaning and coverage of the two terms "loss" and "waste" in different languages, which can happen to be quite different than in English. Such different uses of the same words to cover very different scopes make comparisons between studies and numbers quite difficult and, if definitions are not properly checked and accounted for, can be very misleading. Nevertheless, distinguishing between food loss and food waste, in various ways, is useful: as we will see in this report, these two broad perspectives often relate, very broadly, to distinct types of causes, and are, very broadly, more associated to distinct types of systems.

For the purpose of clarity of terminology, the HLPE retains the most often used approach, the one of the first category of authors above, which links food waste to its taking place at consumer level and food losses to their taking place any stage before the consumer level, *regardless of the real underlying explanatory cause*, and regardless of its "behavioural" character or not, or of its "voluntary" character or not. This terminology has the advantage of being easy to apply and easy to relate to specific data.

In this report the following definitions will therefore be used (Definition 1).

Definition 1 Food loss and waste

Food loss and waste (FLW) refers to a decrease, *at all stages of the food chain from harvest to consumption* in mass, of food that was originally intended for human consumption, regardless of the cause.

Food losses (FL) refers to a decrease, *at all stages of the food chain prior to the consumer level*, in mass, of food that was originally intended for human consumption, regardless of the cause.

Food waste (FW) refers to food appropriate for human consumption being discarded or left to spoil *at consumer level* – regardless of the cause.

Food quality loss or waste (FQLW) refers to the decrease of a quality attribute of food (nutrition, aspect, etc.), linked to the degradation of the product, at all stages of the food chain from harvest to consumption.

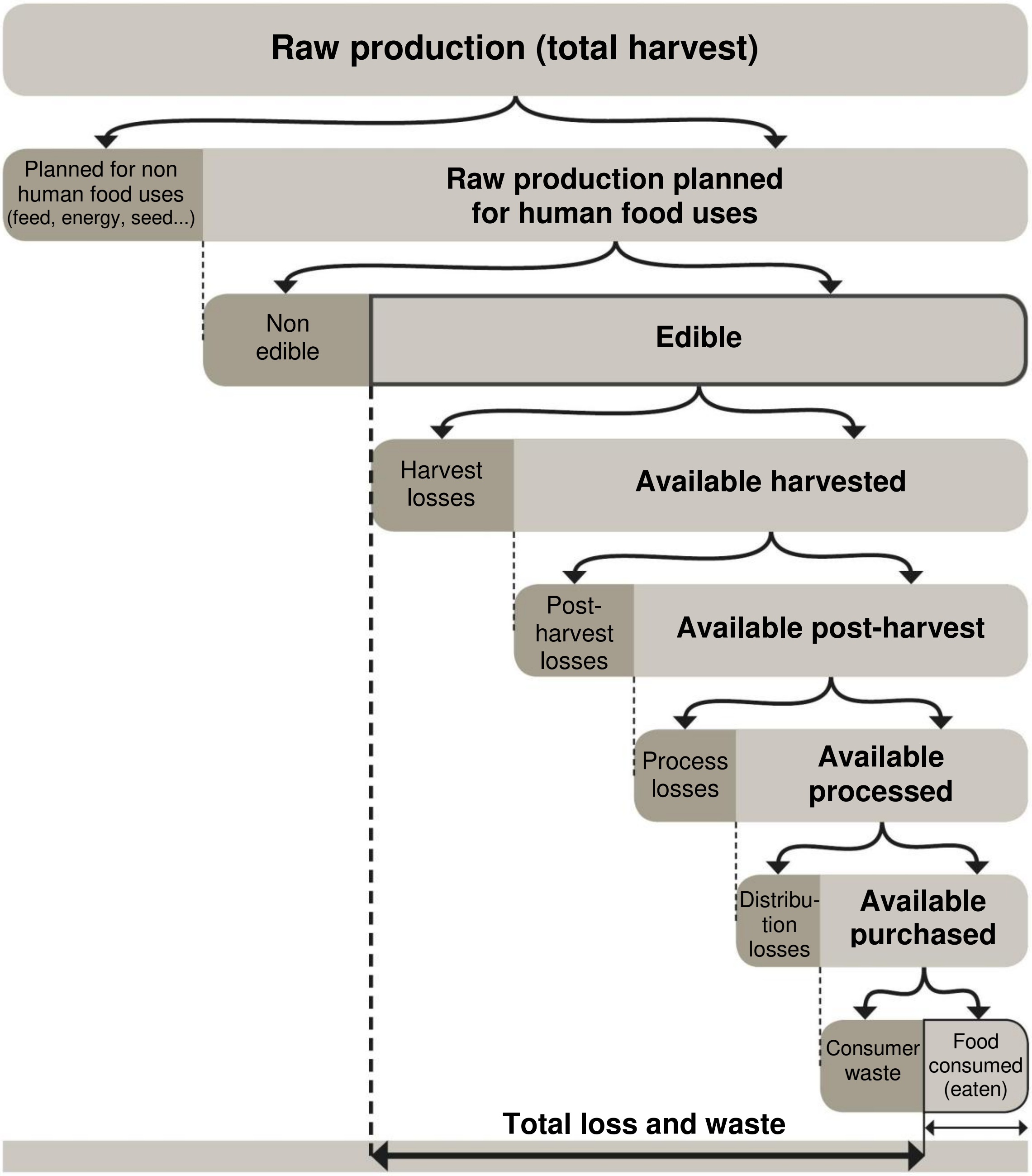
Therefore, FLW occur between the moment when a product is ready to be harvested or harvested, and the moment when it is consumed or removed from the food supply chain.[4] Inedible fractions removed from the food supply chain (e.g. side streams) are not considered as FLW (Figure 1). Neither are yield gaps, conversion of plant products in animal products, and overnutrition considered as FLW, as they are rather related to broader considerations on the efficiency of food systems.

2 Some use "*food waste*" as a generic term. It is often in contexts linked either to waste in general or to a concern about use of natural resources, and in relation to the natural environment or other dimensions. What others call "*loss* is for them a "*waste/wastage*", because they associate it to a "waste" of resources (meaning they could have been used for other purposes). The term wastage is also sometimes used with such a broad meaning.

3 In such waste-related approaches, some, as the Waste and Resources Action Programme (WRAP), distinguish "non-avoidable waste" (defined by them as the non-edible parts of food), and "avoidable waste", which is defined as edible food waste. In the definition used in this report, such "unavoidable waste" is not considered FLW. Under the definition used by FAO (2011) and also in this report, non-edible parts of produce -- what WRAP calls "unavoidable waste" – are never accounted as FLW.

4 A food supply chain encompasses all those activities that help ensure the delivery of finished products to the consumer from the primary producer. Such activities can include storage, transport and distribution, processing, wholesale, retail and consumption.

Figure 1 Schematic representation of the definition of food losses and waste along the food chain



FLW along the food chain: Raw agricultural production is divided into food versus non-food uses, and food uses is further divided into edible and non-edible parts of produce. Total FLW is the sum, at each step of the food chain, of losses and waste of edible parts of food that were originally planned for human consumption. The figure represents the five steps (harvest, post-harvest, process, distribution, consumption) where the mass can be measured and data available in national multi-product statistics, building upon food-balance sheets, as used in FAO (2011a) and described in Gustavsson et al. *(2013). Inside each of these stages, and between each of these stages – and attached to them, FLW can happen for various reasons, including storage, transport etc (see Chapter 2).*

All along the food chain there can be quality decreases (in nutritional quality, in aspect or other quality attributes) without a decrease of dry matter of food. We propose to designate this decrease with the concept of FQLW. Food quality loss is difficult to measure as there can be various ways to approach quality: nutritional qualities are in themselves multidimensional (macro- and micronutrients, vitamins, minerals, etc.). Time is an essential determinant of FQLW, as produce, especially fresh, perishable produce, loses quality over time, before FLW "*stricto-sensu*" happens. FQLW translates into a loss of economic value, by different ways and time frames depending on products. It finally leads to FLW. The way FQLW translates into a loss of economic value is key to explain an important part of FLW. When a food stuff has lost a certain level of quality, it is often thrown away.

1.1.2 FLW and FQLW metrics

What metrics could be relevant to measure FLW and FQLW? Different metrics have different implications in terms of data needs, measurements protocols, calculation results, and on the interpretation of results. Some metrics might be more relevant depending on the different situations or categories of actors, and on the scale at which FLW is assessed.

FLW is generally measured in food mass. Some studies have also used caloric metrics, and other use economic units. FQLW is more difficult to assess and measure, as there are different quality and nutritional attributes, which are not correlated to each other. There is also generally a loss of economic value with increasing FQLW, for instance in case of a decrease of visible quality attributes (fresh products or expiration dates, see Section 2.2.4).

Food mass (FLW)

The usual approach to metrics is to assess FLW in mass, generally the most easily accessible and comparable data at all levels of analysis. This is compatible with the above definition of FLW we use in this report, and was adopted by most of the studies published so far, including the broad study on the extent of FLW (FAO*,* 2011a).

Caloric (FLW)

Another approach is to report FLW in caloric units. Kummu *et al.,* (2012) have converted FLW figures as expressed in mass in FAO (2011a), into calories, using the caloric content of the diverse foods. This leads to giving a greater "weight" to FLW of energy-dense foods in the calculation of FLW. This approach is not to be confounded with the one, conceptually different, used by Smil (2004) to evaluate the efficiency of the food systems (see Section 1.3.1).

Nutritional value (FQLW)

Accounting FLW in mass does not fully take into account the nutritional dimensions: food quantity might be preserved (low FLW levels) as expressed in mass, but this does not necessarily means that proteins quality and nutrients are equally preserved. This is why we propose, in this report, a separate definition for FQLW to account for cases when nutritional qualities are lost without correlated FLW.

For example, the nutrient density of fresh foods is highest right after harvest, especially in fruits and vegetables, but continually declines during storage, and even more rapidly in conditions of inadequate care, handling and storage. Ascorbic acid (vitamin C) begins to degrade immediately after harvest and degrades steadily during storage for all classes of fruit and vegetable products, with "losses" which could reach 100 percent in four days for fresh spinach (e.g. Lee and Kader, 2000). Refrigeration can only slow but not stop the process. And the nutritious quality continues to degrade during prolonged storage of frozen products. Also, nutrients or nutritious by-products can be lost during industrial processing, fractioning or refining of foods. For instance, the polishing of rice and the removal of bran in wheat removes many essential nutrients. The extraction of juice from fruits results in nutrient-rich leftovers, discarded as waste or channelled into non-food use. Significant amounts of nutrients, especially vitamins, are lost during the process of blanching or drying fruit and vegetables.

Conversion of food to processed forms may be essential to preserve the food in mass terms, and desirable from a convenience point of view, but the nutritive value of processed foods may be lower than that of very fresh produce. It is however higher than fresh produce badly preserved, pointing to the importance of processing conditions to avoid nutritional losses.

Finally, indiscriminate practices in food trade such as food adulteration can lower the quality of food due to dilution of nutrient density or destruction of nutrients. It can be due to incorporation of edible/inedible material, non-permitted additives, excessive additives or abstraction of a component. There can potentially be various ways to measure FQLW, depending on the nutrition variable or quality considered, and this is an area for new research.

Monetary (FLW and FQLW)

Some authors also use monetary values as FLW and FQLW metric[5] especially at food chain level. Physical food losses and waste, as well as FQLW, translate into losses of economic value added. Along a food chain, from production to final sale, value is generally accumulated, attached to successive phases of the elaboration of final produce. This is the case obviously for elaborated, processed food produce, but also, in shorter food chains, for fresh produce. Conversely, loss of value added linked to the degradation of the quality of food (FQLW) or to FLW can take place at every step of the food chains. As seen above, time can be an important determinant of FQLW, therefore of monetary losses.

Down the chain, as value added is accumulated to the produce, there is correlatively more value to be potentially lost in case of FLW, down to a possible total economic loss at consumption stage, when consumers spend money to buy produce that they might never end up consuming, and leave to spoil.

Sometimes food chain agents, processors, retailers and market operators, have adopted strategies to avoid suffering complete economic losses in situations when food products have lost quality (FQLW, be it freshness, shape, colour, consistency, taste) to the point that they are "close to being lost" (FLW). Actors of the food chain may accept partial economic losses to avoid such a total economic loss: in doing so they do as if they were anticipating a food loss, trying to mitigate it. Processors can redirect such produce to non-food uses, or to feed, with some economic value. On food markets, prices can go down, when produce remaining to be sold is of lower quality or more perishable, with less lifetime remaining. This strategy has also been adopted by some supermarkets (NRDC, 2013), selling products near the "best-before" date at discounted rates. The latter behaviour leads to lowering the economic loss of the retailer. It nevertheless does not slow the physical "degradation" of the product *per se*, which eventually will risk becoming physically lost at consumer level.

As we will see in Chapter 3, the economic metric to FLW is certainly relevant when devising strategies to reduce FLW, which will need to take into account how the overall economic losses linked to FLW are distributed along the food chain, and to consider also the costs of FLW reduction, meaning that some actors might win, but other might lose from FLW reduction actions.

1.1.3 Current evaluations of the extent of food losses and waste

As mentioned above, studies on FLW can be traced back to two major work streams: studies on *food losses* or *post-harvest losses* for a particular product, generally with the aim of improving the economic efficiency of a particular food chain, and studies *on waste* or *food-related waste* (including packaging), often at local or national level, aiming to reduce it and improve its management.

Some studies give perspectives on FLW in specific parts of food supply chains: production, processing, wholesale, logistics, retail, markets, redistribution, catering and other food services or households (e.g. Hanssen and Møller, 2013). These studies, being adapted to their specific object, are often difficult to compare and amalgamate.

Post-harvest losses have given way to various studies and projects, mainly using agronomic or engineering knowledge, addressing their various causes at each stage of production. One example is for instance the African Postharvest Losses Information System providing postharvest weight loss estimates for seven cereal crops in Sub-Saharan Africa (APHLIS, 2014), at national and provincial scale. APHLIS gathers a network of local experts supplying relevant data and verifying loss estimates; a central database; and a loss calculator to calculate losses from all provinces of the countries in the region. Loss estimates are derived from the best known estimates of the loss for each link in the postharvest chain allowing for crop type, climate and scale of farming. Further corrections are applied for a range of other factors. According to APHLIS, total post-harvest losses for cereals during harvesting, drying, handling operations, farm storage, transport and market storage in the region oscillated between 14.3 percent and 15.8 percent of the production during the period 2003-2013.[6]

A comprehensive preparatory study on food losses and waste across the EU27 investigated causes, quantities, environmental impacts, best practices, forecasts and policy development (EC, 2011). Both

[5] In this section, we restrict monetary loss to the economic value loss attached to the production. This includes accounting for the costs (at market price) of inputs to production at all stages, including labour etc. Some authors go further and include in economic valuations the assessment of the costs in terms of non-marketed externalities (use of natural resources etc.), or of the opportunity costs (what could have been done with the produce that ends up lost).

[6] www.aphlis.net

Eurostat and other national data and estimates have been used and the study estimated EU27 annual FLW at 89 million tonnes, or 179 kg per capita. Limitations in the reliability of the use of Eurostat data, due to a lack of clarity on the FLW definition and methodologies to measure them, have been pointed out as being potentially significant. Additionally, data are missing for some sectors in some EU Member States. Also, it was not possible to confirm that by-products were not included in some instances in manufacturing sector data. Within the FUSIONS project (see Section 3.3.3), further evaluation of the Eurostat system has shown that there are currently formal and methodological elements that make it difficult to use the statistics for generating reliable food losses and waste time series (Hanssen and Møller, 2013).

A national assessment study in Australia has collated and reviewed the quality and nature of 1262 studies on FLW, ranging from regional waste management authority reports and research papers to national studies. This report notes that, while there are many existing food losses and waste studies, they are highly variable, both in terms of geographical relevance and methodology. Accessing much of the data often requires negotiating with a large number of data holders with different concerns about privacy and confidentiality. For some parts of the food stream there is a lack of sufficient data. The study concludes that a more comprehensive understanding is needed to improve the environmental performance of waste management systems, or to improve the use of increasingly scarce resources (Mason *et al.,* 2011).

In the United States of America, the USDA Economic Research Service has put in place a Food Availability Data System[7] that includes loss-adjusted food availability (LAFA) data series. The data series is considered a work-in-progress as the USDA continues to refine the underlying loss assumptions and estimates. Based on this, in the United States of America, FLW were estimated at roughly between 30 and 40 percent of the total food supply in 2010, with 31 percent of the food *available at the retail level* ending up lost or wasted either at the retail or at consumer levels, corresponding to 60 million tons of food (Buzby, Wells and Hyman, 2014).

At global level, the study by Gustavsson *et al*. (FAO, 2011a) entitled "*Global food losses and food waste*" has been the most quoted and used reference on the extent of FLW. The methodology is depicted in Box 1 and results are shown in Figures 2 and 3. It uses partial sources and attempts to bridge knowledge gaps by extending the findings of available studies on comparable products in the same country and/or comparable countries. The study assesses global FLW at a level of roughly one-third of the mass of edible parts of food intended for human consumption, representing about 1.3 billion tonnes per year. This is equivalent to a per capita FLW of 280–300 kg/year in Europe and North America and of 120–170 kg/year in sub-Saharan Africa and South/Southeast Asia.

Kummu *et al*. (2012) used the raw data compiled for the FAO (2011a) study and calculated that this one-third decrease in mass translates in a global FLW level of 25 percent decrease in calorie terms.

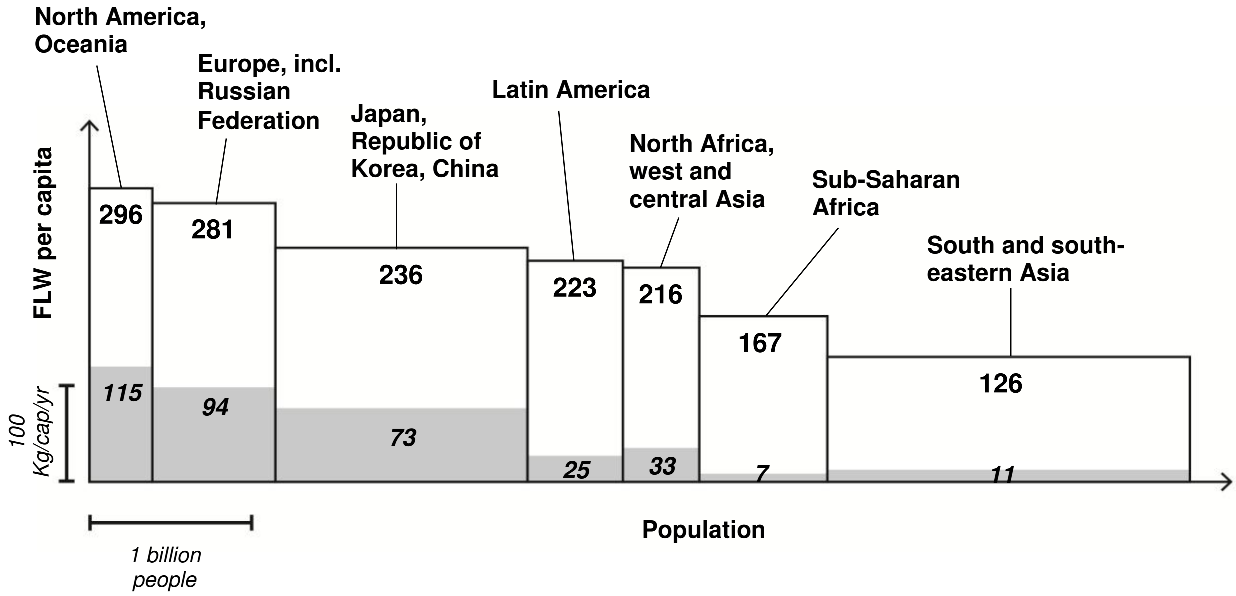
Losses and waste differ widely between products and between regions for the same type of products (FAO, 2011a; Kummu *et al*. 2012). For instance, in Europe, cereal losses and waste are twice as high as in sub-Saharan Africa. On the other hand, in sub-Saharan Africa, milk losses and waste are twice as high as in Europe.

Depending on the products and the regions, the distribution of the losses and waste along the food chain is very different. Globally (FAO, 2011a; Kummu *et al.,* 2012; Parfitt, Barthel and Macnaughton, 2010; Hodges *et al.,* 2010), in middle and high income countries a great share of the food losses and waste occur at distribution and consumption level; in low income countries, it is during agricultural and post-harvest steps (see Figure 3). For instance, in Africa cereals are lost mostly in the first stages of the food chain. In Europe, they are lost mostly at the consumer stage: 25 percent of consumer waste of cereals, against 1 percent in Africa. For fruits and vegetables, the differences between regions are also striking. In Africa, processing and distribution are the weak stages. In Europe, it is at consumption that most FLW occur.

As one can see in Figure 3, losses at harvest stage are significant across all regions of the world. However, as we will see in Chapter 2, these losses do not take place for the same reason: in developed countries, they are mostly due to produce being rejected because of quality standards, therefore to a great extent attributable to causes "down the food chain", and to the consumers.

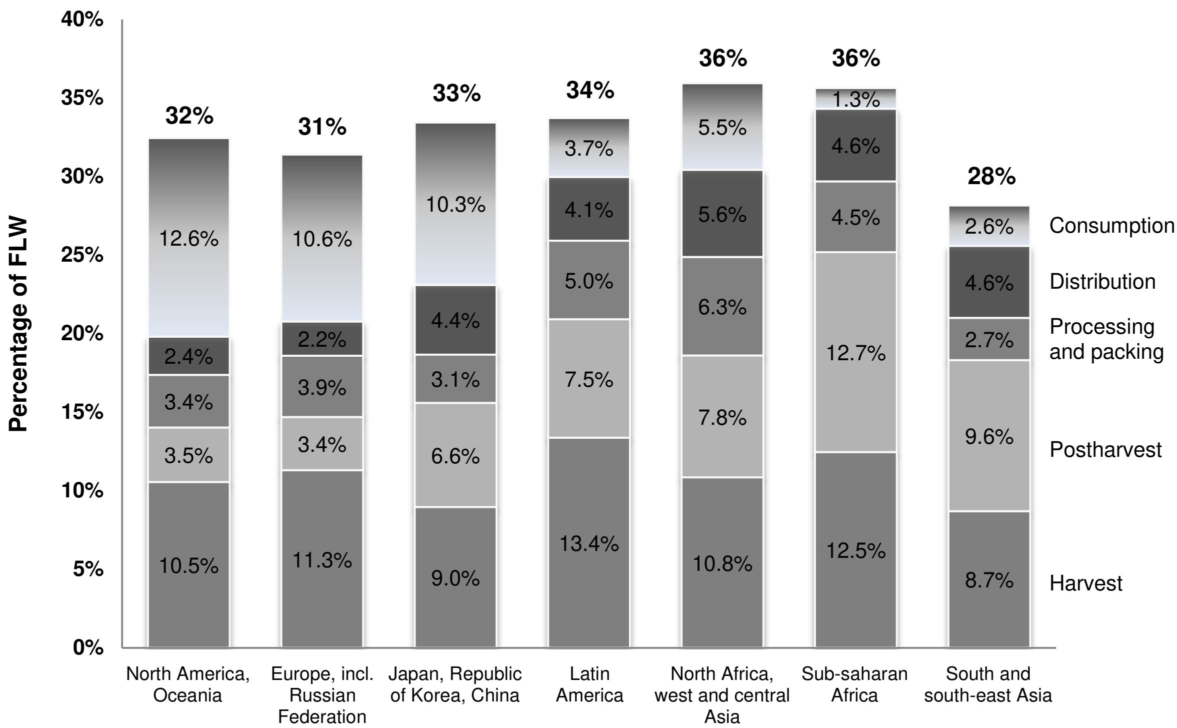
[7] http://www.ers.usda.gov/data-products/food-availability-(per-capita)-data-system.aspx#26705

Figure 2 FLW per capita in the different world regions



The X-axis represents the population of a region or group of countries. The Y-axis shows per-capita FLW in the given region. The grey part distinguishes consumer waste from post-harvest losses within regional food loss and waste. For each region, the area of the rectangle represents total regional FLW. Source: elaborated from Gustavsson et al. *(FAO, 2011a).*

Figure 3 Distribution of FLW along the food chain in the different world regions



The bars represent the percentages lost or wasted at each step of the chain, expressed in percentage of the initial production (edible part originally intended for human consumption, see Figure. 1). Source: elaborated from Gustavsson et al. *(FAO, 2011a).*

Box 1 The methodology of the FAO (2011a) study: "*Global food losses and food waste - extent, causes and prevention*" (Gustavsson *et al.,* 2013)

Absolute FLW numbers were obtained by applying FLW percentages to data from national and regional food balance sheets, using the year 2007 as a base. The production volumes were collected from FAO Statistical Yearbook 2009. Percentages of losses and waste for different regions of the world, different commodity groups and different steps of the supply chain were collected from an extensive literature search and by expert consultation. Different calculation models were applied for each commodity group: cereals; roots and tubers; oilseeds and pulses; fruit and vegetables; meat; fish and seafood; and milk and eggs.

The methodology of the study, described in Gustavsson *et al.* (2013), is challenged by major data gaps for percentages of both losses and waste. Where there are gaps of knowledge, assumptions and estimations were made, based on comparable regions, commodity groups and/or steps of the food supply chain.

For instance, the study assumes an average FLW of 25 percent for the whole group of cereals at the consumer level in Europe, which is an assumption based on a study by the WRAP (2008a) relevant to United Kingdom households, whereby household waste of bread was estimated at 29 percent, and 16 percent for other staple foods. This leads to a result of 22.6 million tonnes of cereal waste at consumer level in Europe, representing 32 percent of the total European consumer food waste. Therefore, one third of the EU consumer waste results from a single point-estimate, based on bread waste data for United Kingdom households.

This example and other similar uses of point-based estimates to assess global waste percentages show that the results of the original Gustavsson *et al.* (FAO, 2011a) study need to be taken with great caution, a fact which the authors of the study acknowledge.

The FAO (2011a) study is however the only global study currently available with FLW data at all levels from production to consumption and encompassing all sectors of food production, including fisheries. Despite shortcomings in terms of data available, the global results of the study, and the order of magnitude found of one-third of FLW (and its declination in developed and developing countries) is coherent with existing studies at regional/national level, as well as with sectoral studies.

Finally, it is important to note that all the studies of global relevance providing estimates of global FLW, published subsequently to the FAO (2011a) study, rely on the same raw data from FAO (2011a). These studies, such as Kummu *et al.* (2012), the WRI study (Lipinski *et al.,* 2013), the FAO, 2013 Toolkit (FAO, 2013a), or the 2013 Report from the Institution of Mechanical Engineers (IMechE, 2013), etc. therefore do not provide independent estimates of the extent of FLW.

1.1.4 Towards harmonized methodologies and protocols to describe and measure FLW

As recognized by many (e.g. Parfitt, 2013), global studies on FLW – all relying on the single source available that remains FAO (2011a) do not hide concerns on the precision of the FLW estimations (see Box 2).

First, concerns exist regarding the reliability, incompleteness and quality of available primary and secondary data. For instance, in many cases, national estimates of FLW result from the aggregation of sub-estimates coming from different years – figures that can be very variable over time, with changing contexts (Hodges *et al.,* 2010). In general, there is simply not enough data on FLW in food supply chains worldwide, either from primary or secondary sources of information.

Second, there is currently no estimation of the uncertainty or margin of error surrounding FLW numbers.

Third, data are rarely reported on a regular, recurrent basis, and there is not much evidence on the evolution of FLW and, currently, except for some exception such as in the United Kingdom (WRAP, 2014) or Norway (Hanssen and Møller, 2013), no estimates are available for past and current trends of FLW, which obviously handicaps the establishment of a clear baseline against which progress in FLW reduction could be measured. As noted by the Organisation for Economic Co-operation and Development (OECD, 2014), "*data collection on FLW tends to be on an ad-hoc basis as a one-off project within a limited time frame and not on a continuing basis*". Use of outdated data can hide improvements (Parfitt, Barthel and Macnaughton, 2010; Liu, 2014).

Different definitions, different metrics, different measurement protocols and the lack of a standard for collection of data adapted to different countries and products: all of this make it difficult – and sometimes impossible – to make comparisons between studies, between systems, between countries. Any FLW number is always a wrong number if not clearly and uniquely associated to the methodology used to produce it. There is also no agreed method to evaluate the quality of data, method and numbers produced.

This situation is a huge barrier to understanding the real situation (what are the identified causes of FLW, what extent of FLW they specifically create?), the estimation of the potential for solutions, of "what needs to be done", and of the monitoring of progress.

This is why there are currently strong calls from many organizations (FAO, OECD, EC, FUSIONS, WRI, UNEP, etc.), for the development of global protocols for the measurement of FLW, taking into account a large number of variables and country specificities, towards a harmonization at global level of definitions and measurement methods, towards the improvement of the reliability and comparability of data, and towards more transparency. The HLPE makes a specific recommendation on the matter (Chapter 4).

1.2 What are sustainable food systems?

In this report, we adopt the following definition of a food system (Definition 2), as adapted from a range of other definitions (e.g. Ericksen, 2008; Ericksen *et al.,* 2010; Ingram, 2011; IPCC, 2014).

Definition 2 Food system

A *food system* gathers all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes.

Thus intended, a *food system* is defined as the sum of all the diverse elements and activities which, together, lead to the production and consumption of food, and their interrelations. A food system interfaces further with a wide range of other systems (energy, transport, etc.), and faces various constraints. Food system is a "descriptive" concept: its definition is not "normative" and does not preclude that a food system will necessarily perform well or generate appropriate food security outcomes, as well as a range of other socio-economic and environmental outcomes.

The concept of food systems, or of food and nutrition systems (Sobal, Khan and Bisogni, 1998) has given way to numerous definitions and conceptualizations. There have also been various attempts to create typologies of food systems. Many of them are constructed on a historical perspective, from "traditional" to "industrialized" systems (Malassis, 1996). Most of them resort to criteria related to the relationships between production and consumption: distinction between producers and consumers, part of consumption produced "internally", distance from which food is coming (Esnouf, Russel and Bricas, 2013). Scale is, of course, key here, with many studies focusing on distinctions between local and global (Gaull and Goldberg, 1993; Goodman, 1997; Feenstra, 1997; Hinrichs, 2000; Kneafsey *et al.,* 2013). To a certain extent, most if not all food systems are interconnected and their sum constitutes "a global food system".

Food systems can be described as encompassing a number of activities which give rise to a number of food security outcomes. Food systems are themselves influenced by economic, social and environmental drivers (and their interactions). In turn, food systems feedback on environment, social and economic drivers (Ingram 2011). There are many different views as to what constitutes a *"sustainable"* food system, and what falls within the scope of the term "sustainability".

Historically, the concept of sustainability resulted from the initial works by the international scientific and development community on the notion of systainable development. This concept was then applied to agriculture, or parts of the food systems. We will start by briefly reviewing these attempts before adopting a holistic view of "sustainable food systems" considering food systems in their completeness and in how they relate to food security and nutrition objectives.

There have been many works around sustainability since the 1980's. This discourse has started in the international discussions around the issues of environment and development, and the work of the "Bruntland" *World Commission on Environment and Development* established in 1983 by the UN-SG, and the release in 1987, of its report "*Our common future*". In this report, "sustainable development" was defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). Sustainability, by essence, having been much discussed in relation to the concept of development, includes a time perspective. As explained by Lang and Barling (2013), the Bruntland report defined sustainability within a multigenerational perspective, and giving equal emphasis to environment, society and economy as key "pillars" on which sustainable development needs to be grounded.

The attempt to link sustainability and food security started also with the Bruntland report (WCED, 1987), which included a seminal chapter entitled, "Food security: sustaining the potential". In this chapter, however, the approach was mainly focused on global levels of production and global availability of food, with the concern that "*there are broad areas of the Earth, in both industrial and developing nations, where increases in food production are undermining the base for future production*".

More recent works (e.g. Pinstrup-Andersen and Herforth, 2008) have shown that the linkages between sustainability and food security are more complex than just the issue of ensuring future global availability of food, given the need to consider access to food at household level.

Until recently, the corpus of works around sustainability and food has mainly been either applied to parts of food systems, for example production – with the issue of sustainable agriculture or sustainable production – or for instance more recently, on consumption, with the issue of "sustainable diets" (FAO, 2012c).[8] Also most approaches tended to emphasize the environmental dimension of sustainability over the two other ones, economic and social. The 2001–2011 Global environmental change and food systems (GECAFS[9]) project was set up to foster research on ways to enhance food security without further degrading ecosystem services. It produced important work on the concept of the food system and on its relationship to food security (Ingram, Ericksen and Liverman, 2010). The preparation of the Rio+20 Conference gave way to important discussions bringing together food security and sustainability of food systems and emphasizing their importance for sustainable development, an example of which is the FAO publication *Towards the future we want: end hunger and make the transition to sustainable agricultural and food systems* (FAO, 2012b).

Considering the sustainability of food systems and the linkages to food security, this therefore requests broadening the perspective of study along three axes:

- from a pure production perspective to a more holistic food system approach;
- from an environmental perspective to a perspective encompassing also the economic and social dimensions;
- from a "global availability" perspective of food security to integrate the accessibility, nutrition and stability dimensions of food security, down to household and individual level.

Such a broadening of the different perspectives mirrors the challenges to define the set of criteria to measure food systems' sustainability (see e.g. Esnouf, Russel and Bricas, 2013; Garnett 2013, 2014).

We propose here, in line with the original broad approach of sustainability, to define "sustainable food systems" by their capacity to ensure the positive outcomes of a food system, food security now and for future generations. Indeed, the original concept of sustainability brings a time dimension, which means that the functioning of a "sustainable food system" should not undermine the economic, social and environmental basis that grounds food security of current and future generations, but rather contribute to enhance it. In doing this, the three dimensions of sustainability interact with the four dimensions of food security (availability, access, utilization and stability).

8 In 2010, an FAO-Bioversity symposium produced as an outcome one definition of "sustainable diets": "Sustainable Diets are those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources."

9 http://www.gecafs.org

Based on the above, we adopt in this report the following definition for a sustainable food system (SFS, Definition 3).

> **Definition 3 Sustainable food system**
>
> A *sustainable food system* (SFS) is a food system that ensures food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition of future generations are not compromised.

Under this definition, the most important criteria of a sustainable food system is ensuring today and tomorrow's food security. In other words, a food system that does not ensure food security and adequate nutrition cannot be called sustainable.

But ensuring food security and nutrition *today* would not be sufficient for a food system to be called sustainable. Indeed, "*the need to ensure that the economic, social and environmental bases to generate food security and nutrition of future generations are not compromised*" entails the need to address numerous issues in the economic, social and environmental dimensions, at different geographical and time scales, given the objective not to compromise the satisfaction of the needs of present and future generations.

The sustainability of food systems is determined by environmental, economic and social factors. Many of them are inside food systems, and part of them are outside the food system (such as social protection).

Priorities to determine what makes or not a SFS will thus depend on the context of each country or subsystem: scarcity of resources, importance of agriculture as income and/or jobs provider, etc. "How different resources are used by food systems" is one of the key dimensions to assess their sustainability. Overuse of resources, at the system level, generally undermines the environmental, but also the economic and social, basis of food security, with possible impacts in all the dimensions of food security. Trade-offs can take place between the different dimensions of sustainability, and these trade-offs can manifest themselves differently at different scales.

An important conceptual consequence of positioning food security and nutrition as primary criteria to assess the sustainability of food systems is that the adequate/better provision of food security and nutrition provides a guide to prioritize among trade-offs. Food security in itself cannot be one trade-off variable.

1.3 FLW, sustainable food systems and food security

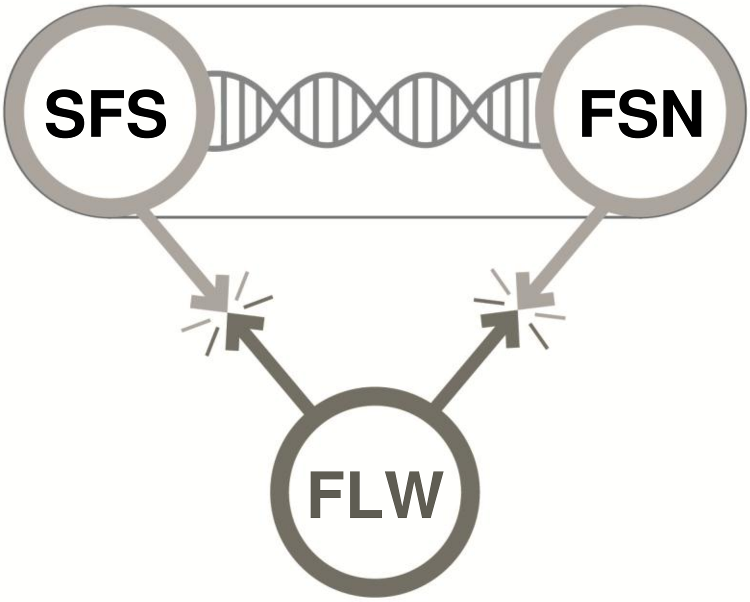
We have seen that the sustainability of food systems is a condition for them to ensure food security now and on the long term (Section 1.2).

FLW are often presented in relation to the sustainability of food systems, or rather to their unsustainability, either as a result of unsustainable food systems or as a cause of them. Therefore FLW hinder reaching the overarching goal to ensure sustainable food security (Figure 4). In this section, we develop the relationships between FLW and the sustainability of food systems, as a basis to understand the links between FLW and food security.

1.3.1 FLW and SFS

The production of food, which is ultimately not eaten, whether it is lost during the production and transformation processes or wasted at the consumption stage, entails a "waste" of economic or natural resources. It also brings social impacts. In this section, we review impacts of FLW on the three dimensions of the sustainability of food systems – economic, social and environmental. These impacts could be described at three levels (Table 1), namely: at the level of the households and individual enterprises (micro-level), at the level of the production chain (meso level), and at the more general level of society (macro level).

Figure 4 Schematic representation of the conceptual links between sustainable food systems, food security and nutrition, and food losses and waste



Sustainable food systems (SFS) and food security and nutrition (FSN) are tightly linked as per the very definition of SFS (see Definition 3). Food losses and waste go against the sustainability of food systems and against food and nutrition security.

What do we mean by impacts of FLW? First, one can understand today's FLW's impacts only relative to a situation where there would be "less" food losses and waste. Therefore, the notion of impact is fundamentally a comparative one, and must be assessed with respect to a reference. One has also to distinguish between "explicit" impacts of FLW (often linked to the existence of a physical flow of FLW, and its end destination), and the "opportunity" impacts of FLW, measured by the economic, social or environmental value of a foregone better alternative and a situation with less FLW.[10]

Most of today's analyses agree that a reduction of food losses and waste would lead to food systems being more sustainable, with positive economic, social and environmental outcomes, outweighing the cost of action (and possibly with negative cost actions).

They reflect the fact that the optimum pathway for sustainability is not zero food loss, but a situation with certainly substantially less food loss and waste than today. Indeed, incremental costs of efforts to reach very low levels of food loss and waste might, at a certain point, prove too costly (including social and environmental costs) and overweigh the economic, social and environmental benefits provided by the additional reduction.

Analyses of economic impacts of food losses and waste considering global aspects are still scarce. A study evaluated the cost of FLW in South Africa by attributing a representative price to each commodity group at each stage of the value chain. It estimated the value of FLW at USD7.7 billion, equivalent to 2.1 percent of South Africa's annual GDP (Nahman and de Lange, 2013).

FAO has assimilated FLW as a global economic negative externality (FAO, 2013b), and has launched works towards full-cost accounting of FLW. By applying FAOSTAT traded prices for the year 2012 to FLW quantities, FAO made a preliminary estimation of the direct economic cost of the 1.3 billion tonnes of FLW at close to USD 1 trillion per year. This number does not include externalities and other social and environmental costs and damages, which FAO estimates at USD 900 billion and USD 700 billion, respectively (FAO,2014a).

10 This reflects the fact that the optimum pathway for sustainability is not zero food loss, but a situation with certainly less food loss.

Table 1 Examples of potential impacts of food losses and waste on the sustainability of food systems

Level / Dimension	Economic	Social	Environmental
Micro (household or individual enterprise)	• Businesses and consumers spend a larger portion of their budget on foods that will not be sold or consumed	• Lower wages • Consumers with fewer resources for purchase • Lack of products	• Amount of garbage and waste • Contamination of individuals in rural and urban areas
Meso (food chain)	• Imbalance in production flows and need for more investments such as construction of silos and warehouses for intermediate stocks • Profit reduction • Inefficiencies in supply chain • Costs of disposal and treatment of waste	• Low labour productivity • Difficulties for companies to make their planning	• Multiplication of landfills
Macro (food system and beyond)	• Unrealized economic effort • Public investment in agriculture and infrastructure being less productive and turning into an opportunity cost • Reduction in financial resources for investment in other areas	• Higher level of food prices and difficulties in access to food • Larger number of people below the poverty line	• Pressure on natural resources: water and soil • Emission of greenhouse gases • Occupation of forests and conservation areas • Depletion of fishery resources; • Pressure on wildlife • Greater spending on non-renewable energy

With regard to economic impacts to food chain actors and to consumers, different actors/agents suffer different economic impacts and net costs (or even gains), which depend on their position in the food system. Beside the economic cost of FLW (see supra), other analyses have highlighted the fact that losses and waste contribute to higher demand and thus to higher prices (Stuart, 2009; HLPE, 2011). Any effect of price increase due to FLW is different for net sellers versus net buyers of food (see similar analysis on the effect of food price increase and food security in HLPE (2011, 2013a). Also, depending on their market or purchasing power, and/or on their position and capacity of coordination in the production chain, some agents may suffer less from FLW and “push” the costs of inefficiency to less well-positioned agents. In non-competitive markets, most likely the consumer ultimately pays for the inefficiency and economic losses in the production process. In markets where there is greater competition, economic losses can be assumed by subaltern agents that under contract must submit to the standards imposed by the "chain coordinator" (often a major supermarket company, a trader or even a processing industry). However, even in those cases where there is competition, the inefficiency of the food systems always translates into a higher price of food for consumers, everything else being equal. Large amounts of FLW lead, everything else being equal, to proportionally less efficient outcomes of public resources used for productive programmes for agriculture, capacity building, training and subsidies.

With regard to social impacts, the high volume of losses in agriculture in developing countries ends up impacting also on labour productivity (marketable output per worker) and therefore on wages, which in turn can slow down the expansion of the consumer market, which would have boosted the producers for the acquisition of new technologies. From the social point of view, this is a vicious cycle that reduces the availability of resources both in the hands of producers and consumers. It is challenging to exit this cycle. Production cost is an important decision element at micro level.

With regards to environmental impacts, FLW entails both a needless use of resources used to produce the food lost and wasted, and the impact of putting waste at disposal, with emissions of methane, a potent greenhouse gas (GHG).

Recent studies have attempted to quantify the amount of resources “wasted” when food is lost or wasted. Most of them use simple proportional calculation estimations of the environmental impact of food production, applying the same average value to the amount of food estimated to be lost. However, such a one-to-one relationship between FLW and environmental impact based on global averages can only be a very rough first order estimation, as the environmental impact of food (resources used, land, water, energy, etc.) varies according to the way and place of production and also, importantly, to the stage where the loss or waste occurs, especially for energy.

Life cycle analysis studies include the “end-of-life” component of food, with the impact of different treatment systems of food waste (end-of-life technology): composting, digestion and landfill of household and/or industrial food/organic waste. Most studies estimate so-called “footprints” that measure the various ways resources are used or needed, or external impacts generated throughout the life cycle leading to the production and discard of a unit of food:[11]

- The carbon footprint of global FLW, without accounting for GHG emissions from land-use change, is estimated to be 3.3 Gtonnes of CO_2 equivalent, an amount equivalent to 6–10 percent of anthropogenic greenhouse gas emissions (Vermeulen, Campbell and Ingram, 2012).
- Food loss and waste is also water “waste” (Lundqvist, de Fraiture and Molden, 2008), as large quantities of water are used to produce the lost food. From the environmental perspective, food losses and waste account for more than one-quarter of the total consumptive use of finite and vulnerable fresh water and more than 300 million barrels of oil per year. Globally, the blue water footprint (i.e. the consumption of surface and groundwater resources) of food losses and waste is about 250 km^3, which is equivalent to three times the volume of Lake Geneva (FAO, 2013a).
- According to FAO (2013a), produced but uneaten food occupies almost 1.4 billion hectares of land; this represents close to 30 percent of the world’s agricultural land area. In a study on global resource productivity practices by the McKinsey Global Institute (Dobbs *et al*., 2011), reducing food loss and waste was ranked in the top three of measures that will contribute to improved productivity of resources, pointing to the fact that a reduction of consumer food waste in developed countries by 30 percent would save roughly 40 million hectares of cropland.
- It is difficult to estimate the impacts on biodiversity at a global level; however food losses and waste clearly contribute to increasing the negative impact of intensification of agriculture and of agriculture expansion on biodiversity (Stuart, 2009; FAO, 2013a).

Finally, in terms of environmental impacts, it is important to note that consumer food waste has a greater carbon, GHG, land-use, water, nitrogen or energy footprint than a similar mass of post-harvest loss. This is due to the inclusion of the footprints of transport, packaging, processing, distribution and preparation at home, all of which is finally “embedded” in consumer waste. For instance, on average consumer waste is equivalent to eight times more energy “waste” than post-harvest loss (Dobbs *et al.,* 2011).

Efficiency, together with resilience and equity, form a key dimension of SFS (Place *et al.,* 2013). There are various ways to appreciate the efficiency of a food system, some of them using the notion of losses and waste, such as Smil, 2004 (see Box 2). For a given quantity of food consumed, FLW leads to mobilizing more natural resources. The existence of FLW testifies therefore of an “inefficient” food system in its resource use. Increasing efficiency is one key way to improve economic, social and environmental performance of food systems. Therefore FLW is one more reason, following considerations of the challenges to feed the world in 2050 (Bruinsma, 2009), as well as of the intersection of challenges related to the need to ensure food security in a context of climate change (HLPE, 2012) to reckon that efficiency improvements in the food system are key to their evolution towards sustainability.

[11] See for example Garnett (2011), Ridoutt *et al.* (2010), Chapagain and James (2013), Vanham and Bidoglio (2013), Grizetti *et al.* (2013), Wirsenius, Azar and Berndes (2010) for some examples or case studies of FLW’s life cycle or environmental footprint.

Box 2 Calorie losses along the food chain, including food losses and waste

Some studies (e.g. Smil, 2004) have adopted a "caloric" approach to measure the efficiency of food chains, including FLW, by which "calorie loss" is estimated in the whole food system, i.e. the difference between (i) the potential of the food system to produce edible calories and (ii) human daily calorie requirements.

This conception implies adopting the lens of the "caloric" efficiency of the food system, assessing how the food systems, plants and animals, performs at transforming original calories into human food (vegetal or animal), and how ultimately humans use this food in an efficient way. In that perspective, for Smil (2004), excess consumption of calories over daily requirements is assimilated to a wasteful use of food.

1.3.2 FLW and food security

Food lost or wasted while people go hungry is first of all a sign of a global food system that does not fulfil adequately its function – whatever the reason. FLW are often taken as a symbol of both inefficiency and inequity of current food systems.

However, real causes of hunger and malnutrition are very complex and cannot be reduced to the existence of FLW, nor to food availability concerns. Therefore one should be careful in being too simplistic in associating global FLW to global food insecurity. Any reduction of FLW in food-secure or exporting countries will not necessarily translate into increased availability and supply in food-insecure countries.

Rather, FLW testify the existence of an imbalance in the availability and accessibility dimension in the global food system: this is exemplified by the relative importance of "*fateful*" food losses in food-insecure countries (fateful as not being wanted but endured), versus "*behavioural*" food waste in food-secure countries (behavioural as being the result of a "choice to discard" food that could have been eaten). It is also exemplified by the fact that, given our definitions of food loss and food waste, producer countries and net food exporters have a proportionally higher losses volume and that high-income countries, which consume more food, have a higher proportion of food wasted.

What could be the impacts of FLW on food security? It starts with three main ways, often presented in a simplistic manner in the existing literature.

- First, a reduction of global and local availability of food.
- Second, a negative impact on access due, for consumers, to raising prices of food or, for actors along the chains, to economic losses.
- Third, a longer-term effect through unsustainable use of natural resources on which the future production of food depends.

In addition, two relationships between FLW and food security and nutrition are less explored in the literature. One relates to quality and nutrient losses, which negatively impact nutrition. The other relates to the "stability" dimension of food security and what characteristics a food system should have to assure it, especially given the "variable" nature of food production and consumption, and therefore the need for appropriate "buffering" mechanisms to handle the variability of production and consumption in time and in space.

Availability

The impact of food losses and waste on *local* availability of food and thus on *local* food security is an old topic. At the level of a household (or of a community) *under strong food availability constraints*, it is quite a mathematical, one-to-one relationship, with any gain in FLW resulting in more food security, and conversely FLW representing a challenge to food security.

What is new is the importance given to *global* food losses and waste as a *global* food security issue, with local consequences. Mechanically, at global level, FLW translate also into food availability reduction (be it expressed in mass, in calories, or in nutrients).

The issue has been raised first from a natural resources point of view, as part of growing concerns on the capacity of the global food system to be able to satisfy a growing demand (see infra). It is also increasingly mentioned as a sign of unsustainable, inefficient and unfair food systems, with food not distributed according to needs but to wealth. Applying a simple proportional calculation, which is merely useful to get an order of magnitude without implying whatsoever a cause-effect relationship, 1.3 billion tonnes of food lost annually is an amount that could equivalently feed the 842 million people (12 percent of world population) that were estimated to be suffering from hunger in 2011–13 (FAO, 2013b).

How food losses and waste ultimately impact the availability of food is to be considered within scales, but also across different regions. For cultural or for economic reasons, some systems generate "waste", which for another system is useful resources or food, therefore providing a positive impact on sustainability. This is particularly the case for some parts of animals, such as offal, which can be considered non-inedible in some countries, while edible in other. In fact, this notion of "inedible" tends to expand for rich consumers and to cover "less-preferred" and thus less-marketable parts. Trade movements leading to transferring food parts or by-products from regions where they are not consumed to regions where they are demanded could be seen as a contribution to the reduction of food losses and waste, as well as a contribution to food and nutrition security of poorer people (see Box 3). However, it can also have impacts on other dimensions of sustainability, as the gains for producers in the exporting country and for consumers in the importing country have to be weighed against the impacts on the producers in the importing countries, confronted with the concurrence of cheap imports. In some cases it can also raise food safety considerations (that should be harmonized) and nutrition concerns, as shown by the controversies on international trade of turkey tail and mutton flap that leads to a concentration of the consumption of very fat parts in some countries.

Box 3 Valorization of tuna by-products: an example linking FLW reduction and food and nutrition security

Tuna provides an example of diversified valorization of parts of the fish. The canning industry generates a considerable amount of by-products and the practice of utilization of these by-products varies in different geographical regions. Thailand is one of the largest producers of canned tuna and the by-products are mainly utilized as tuna meal, tuna oil and tuna soluble concentrate. In the Philippines, most of the canning industry by-products are converted to tuna meal, but black meat is also canned and exported to neighbouring countries. Edible tuna by-products from the fresh/chilled tuna sector, such as heads and fins, are used for making soup locally, and visceral organs are utilized to make a local delicacy or for fish sauce production. Scrape meat and trimmings are also used for human consumption.

Source: Globefish, 2013.

Access to food

A very controversial issue is to what extent consumer food waste in rich countries has an influence on access to food of poor consumers or to what extent reducing consumers' food waste would improve global food security. What are the socio-economic impacts/consequences of FLW? What are the relationships between the amount of food lost and wasted and the price of food? Can policies to reduce food losses and waste, everything else being equal, lead to a reduction of the overall effective demand, and thus to less pressure on the price system (including for non-food agro-resources)? With what consequences for the income of producers and the purchasing power of consumers?

As we will see in Chapter 3, there is currently a lack of quantitative studies to describe the impact of FLW on food prices. Only a handful of theoretical papers (e.g. Rutten, 2013) are available. What do they tell us?

Everything else being equal, it is generally accepted that global FLW, as part of an increased global demand for food, feed, and biofuels lead to tighter food commodity markets (see for instance HLPE, 2011, 2013a), therefore to higher food prices than if there were no FLW, with concerns on the effects on the poor.

Therefore, according to economic theory, higher FLW, which may lead to higher food prices, are likely to lead to larger supply of food, therefore acting to increase availability. FLW, in contributing to higher prices, contributes to an increase of supply. The supply and demand equilibrium will take place at higher production levels and higher prices with FLW than without.

The net effect of such FLW and food price increase on food access ultimately depends on (i) whether a household is net buyer or net seller of food; (ii) how large its food losses and waste; and (iii) how important the food budget is within the household budget. There is a well-known decreasing relationship between the household income and share of food expenditure in the household budget, established from the comparison between countries or in the same country between different income classes (Seale, Regmi and Bernstein, 2003; Hicks, 2013). In developing countries, where food costs represent a significant portion of the domestic budget, FLW can have a disproportionate impact. In richer countries, spending on food does not exceed 15 percent of the income of households, with approximately half of these expenses occurring through food consumption outside the home. In these richer countries, but also for the middle-class households in countries in transition such as China (Huang, 2013), even if they can be significant, economic losses caused by FLW at consumer level do not significantly impact livelihood. The situation is very different in low-income countries where the cost of food comes to represent more than 70 percent of the household expenditure, as is in Myanmar, 53 percent in rural India or 54 percent in Azerbaijan.[12]

Following this line of thought, Trueba and MacMillan (2011) have proposed the establishment of a "*global mechanism to cut food waste and over-consumption*" by which countries would voluntarily subscribe to a system of per-capita food consumption targets, agreeing to pay penalties in case of failure to meet these goals, with related funds to be used to fight hunger and malnutrition.

Nutrition/utilization

A key issue, often underestimated, is the impact of FLW on nutrition. As mentioned above, some studies (Kummu *et al.,* 2012; Lipinski *et al.,* 2013) made a first attempt in transforming FAO (2011a) figures on FLW (expressed in mass terms) into calories. Such an analysis, however, fails to take into account other nutritional dimensions like micronutrients such as vitamin A, vitamin B12, iron, zinc and iodine.

Fruits and vegetables are sources of important micronutrients and bioactive components, as well as of organic acids and vitamin C, which promote iron absorption. They have a proven role in preventing micronutrient deficiencies and the related diseases. Fruits and vegetables also account for the highest quantitative food losses and waste, pointing to the importance of minimizing their loss or waste from a nutrition perspective. Other nutritionally important foods are those with high iron levels, in a situation where one-third of world population suffers from iron deficiency anaemia. And this is of particular importance as consumption of fruits and vegetables, as well as of fish (see HLPE, 2014) is increasing particularly rapidly and especially as fresh. It has also to be considered with changing modes of buying food, less often.

Such considerations also call for an extension of the mere notion of "*quantity*" (be it mass or calorie) of loss and waste towards integrating *quality* aspects in the measure and in the issue of reduction of food losses and waste, and led us to propose the concept of FQLW (see Section 1.1.1)

Food-safety considerations are an important factor in the relationships between food losses and waste and food security and nutrition. First, food security and good nutrition implies the provision of safe food. Ensuring that only safe food is consumed requires mechanisms leading unsafe food to exit the food chain, therefore leading mechanically to FLW. Food losses and waste that take place because of food-safety concerns – and the need to discard unsafe, dangerous food – contribute to ensuring the "food safety" aspect of food security, but they have a negative impact on availability and on access for consumers, who need to replace the food discarded for food-safety reasons. This has also an impact on prices.

Stability

From a theoretical point of view, to ensure food security one needs to ensure availability of food above the strict minimal nutrition requirements. A system too tight between supply and demand will drive food prices up to unacceptable levels: there is therefore a need for some margin of production over demand.

The more there is variability in production (as well as in consumption), the more the existence of such a buffer of "overproduction" might be important to ensure food security, even if, *ex-post*, some of that food might be lost or wasted. There is a value to the existence of a quantitative margin, and a certain degree of losses and waste, to enable this buffering system to work.

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[12] Data from ILO LABORSTA. The expenditures in Myanmar are from the year 2001, rural India and Azerbaijan from 2003.

The main issue is then how to valorize the extra production, and how to adjust the production, transformation, storage and distribution capacities to manage the surplus, in order for it to be valued or consumed either elsewhere or later.

Considering the stability dimension of food security has important implications on how to understand any quantitative goal of FLW reduction, such as for example the objective of “zero loss and waste” by the UN Secretary-General. This objective cannot be understood as attempting a “zero margin” on food availability with respect to food needs, at each point in time and everywhere. It rather needs to be understood as attempting an optimal functioning of the buffering mechanisms (at production, transformation, conservation and trade levels), which allow managing the necessary amount of overproduction and its variability, in a way to ensure the stability of food security with minimum losses and waste.

More generally, FLW can often be the result of strategies to avoid the risk of not having a certain product at disposal, at whatever stage of the food chain, including consumption.

In the following chapters, we look more in depth at the causes and their dependencies (Chapter 2), the solutions at different level including systemic approaches (Chapter 3) in order to derive practical recommendations to build strategies to reduce FLW for SFS and FSN (Chapter 4).

2 CAUSES AND DRIVERS OF FOOD LOSSES AND WASTE

Identification of causes of FLW is primordial to identification of solutions to reduce them, and priorities for action. Some studies on FLW (Parfitt, Barthel and Macnaughton, 2010; FAO, 2011a; Hodges *et al.,* 2010; Hodges, Buzby and Bennett, 2011) have identified different individual causes of FLW, as much as several hundreds, resulting from a very wide range of antecedents. The importance of these antecedents varies greatly according to the produce, the stage of the food chain considered, and the context.

Losses and waste along the food supply chain often result from interrelated causes. Just as in a conveyor belt, actions at one stage in the chain can affect the whole chain, some can be traced back to harvest or even pre-harvest. This invites looking at the food supply chain as a system of interrelated steps, with critical control points, considering any action (either causes of FLW or ways to mitigate them) on a particular stage not in isolation but as part of the whole food chain.

In doing so, one can see that all the causes are not exactly "at the same level". There are "immediate" causes of FLW, linked to how individual actors deal with various "primary" effects of a biological, microbial, chemical, biochemical, mechanical, physical, physiological or psychological nature that affect food along the chain and can lead to losses or waste. But these causes may in fact result from other, secondary, reasons, linked for instance to how actors are more or less well organized together (e.g. transformation that renders the product useless at a later stage of the chain, etc.), on economic and market conditions along the food chain (product ending up being unmarketable, etc.), or due to more systemic causes.

This report proposes to disentangle the complexity and diversity of causes in organizing their description among three different "levels of causes", depicted in Figure 5.

i. First, "micro-level" causes of FLW. These are the causes of FLW, at each particular stage of the food chain where FLW occurs, from production to consumption, that result from actions or non-actions of individual actors at a stage, in response (or not) to external factors.

ii. Second, "meso-level" causes of FLW. These include secondary causes or structural causes of FLW. A meso-level cause can be found at the same or at another stage of the chain than where FLW happen, or result from how different actors are organized together, of relationships along the food chain, of the state of infrastructures, etc. Meso-level causes can contribute to the existence of micro-level causes, or determine their extent.

iii. Third, "macro-level" causes of FLW. This higher level accounts for how food losses and waste can be explained by more systemic issues, such as a malfunctioning food system, the lack of institutional or policy conditions to facilitate the coordination of actors (including securing contractual relationships), to enable investments and the adoption of good practices. Macro causes are those that favour the emergence of all the other causes of FLW, including meso and micro causes. In the end, they are a major reason for the global extent of FLW.

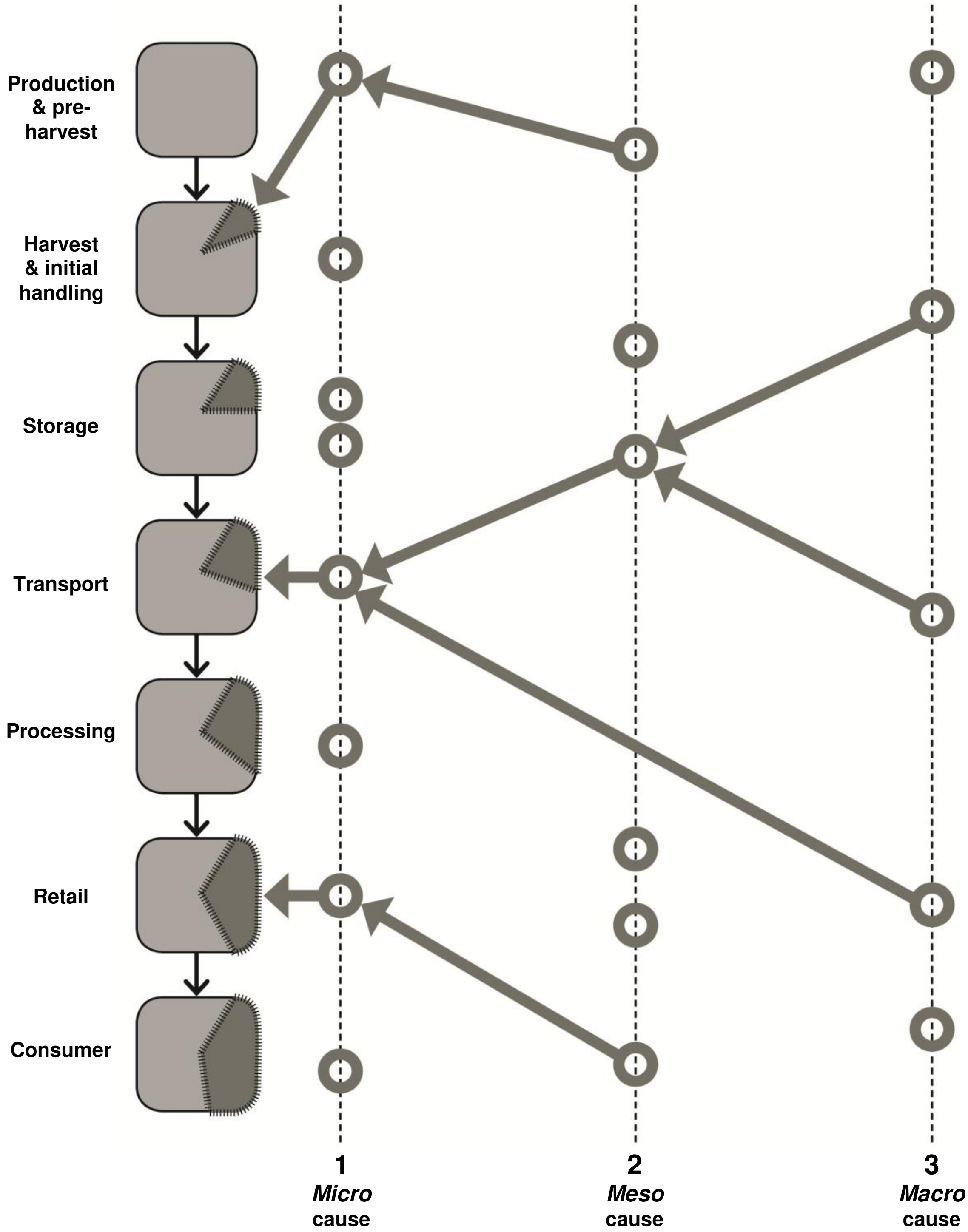
This is why, in this chapter, the causes and drivers of FLW will be considered first from a supply chain perspective, going along the food chain (Section 2.1), identifying "stage-specific" reasons for FLW at each stage of the chain from the field to the consumer. This includes pointing to micro-causes of FLW along the chain, and also to actions (or lack of action) at specific parts of the chain that can lead to FLW in other parts of the chain. We will then describe some meso causes (Section 2.2), and macro causes (Section 2.3), cutting across all stages of the food chain.

Understanding the "organization of causes" of FLW is key to addressing them. It will thus also support the presentation, in Chapter 3, of the solutions to reduce FLW, with actions at different levels.

2.1 Stage-specific causes of FLW along the food chain

The following subsections review the stage-specific causes of FLW at the different stages of the supply chain from pre-harvest/production, harvest, post-harvest, storage, transformation, distribution and retail, down to consumption. These causes are very diverse and also very dependent on products and local situations. Most of the stage-specific causes described below are micro-causes and in reviewing them, we will also point, the case being, to the meso-causes (such as market conditions, market requirements, etc.) that influence them. We also describe, when relevant, how a cause can lead to FLW at one step of the chain, but also at subsequent stages.

Figure 5 Losses along the food chain and organization of causes of FLW



The food chain is represented here in the left of the figure in a schematic way: depending on produce, location, etc. the real order and succession of the different steps can vary and can form very complex chains. Food losses and waste at each step of the food chain can result from micro-, meso- and macro-causes. Here a micro cause of food loss at the stage of transport is represented. One meso, and one macro-cause also happen to influence the micro cause. The meso-cause is in turn also influenced by two separate macro causes. For instance, in the case of transport, one example of micro-cause is the rough handling of raw produce. Related meso-causes could be for example the absence of properly trained loaders, and/or of proper packaging or logistic solutions. Related macro-causes for example could be found in the economic environment leading to low-paid, untrained loaders, and poor infrastructure.

2.1.1 Pre-harvest factors and produce left unharvested

There is damage in the field before harvest due to biological and biotic factors such as weeds, insect pests and diseases. They can be important,[13] but they are not included in the scope of "food losses and waste" (see definition in Chapter 1).

However, pre-harvest conditions and actions in the field can indirectly lead to losses at later stages in the chain, as differences in production and agronomic practices can result in different quality at harvest, different suitability for transport and shipping, different storage stability and different shelf-life after harvest (Florkowski *et al.,* 2009).

Pre-harvest factors driving post-harvest food losses (qualitative and quantitative) can be divided into four groups: choice of crop varieties for the location and for the target market; agronomic practices (including fertilization/nutrient management, water management, pest/disease management, pruning, staking, bagging, etc.); biological factors and environmental factors. These factors can lead to failure to attain desirable quality attributes which leads to a high percentage of rejects/culls.[14] Obviously, losses and waste owing to these factors vary according to the different types of cultivation, seasons and different production areas. Significant differences exist at this stage between developed and developing countries.

The choice of the right variety, adapted to a given location (production site) and meeting the requirements of the target market[15] in terms of quality specifications and time to maturity is an important consideration at the production stage (Kader, 2002). Wrong variety choices result in produce of inferior quality leading to high losses from culls. For some cereals, such as maize, wheat and sorghum, choosing varieties that are prone to logging in regions where winds are prevalent contributes to high losses. An equally important cause of food losses in cereals is planting poorly adapted varieties for a given location, e.g. those that may mature during the rainy season predisposing them to fungal infection.

For fruits and vegetables, agronomic practices during the production phase greatly contribute to the product's quality (visual and nutritional). Poor practices can lead to high losses. Pre-harvest pest infestation is known to be a major contributor to post-harvest losses in fruits, as some of the latent infestations only manifest themselves post-harvest (Thompson, 2007). Poor water and nutrient management contribute to poor produce quality, resulting in a high percentage of culls during grading. Unfavourable environmental conditions such as heavy precipitation result in high disease incidents, brittle vegetables, fruits with low brix, among other defects. On the other hand, high temperatures have been reported to cause physiological disorders such as solar yellowing in sweet paper and cauliflower, sunscald in apples and mango (Postharvest Hub, 2008). For grain crops, temperature extremes are reported to predispose to aflatoxin contamination rendering food unsafe and therefore discarded.

Some produce is left unharvested because of failure to meet certain quality standards (shape, size, weight) dictated by the processors, retailers or target markets (Stuart, 2009), significantly contributing to FLW. For example, in Italy in 2009, 17.7 million tonnes of agricultural produce were left in the fields, representing 3.25 percent of total production (Segrè and Falasconi 2011). In the United States of America, it is estimated that, on average, 7 percent of planted fields are not harvested each year.

Sometimes failure to harvest is due to meso, economic reasons such as low market price at the time of harvest and high labour cost. If a crop matures when the demand is low or notably inferior to the production (due to glut or alternatives), some producers opt to leave the crop in the field as the returns do not justify the cost of harvesting and transport. Conversely, some growers sometimes overproduce to hedge against uncertainties of weather, pest attacks, uncertainties of demand from retailers, and to ensure adherence to contractual obligations with the buyers. Some also plant more area to speculate on high prices. The excess produce is left unharvested, or is harvested and sold to processors or feed industries at lower prices and with lower returns for the farmer (FAO, 2011a), contributing to oversupply leading to low prices, which in turn results in more of the produce left in the fields.

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[13] According to Oerke (2006), the pre-harvest damage attributed to pests is estimated to be 26–29 percent in mass of soybean, wheat and cotton, 31 percent in maize, 37 percent in rice and 40 percent in potatoes.

[14] For instance, the exigencies in terms of quality are an important meso-cause leading to FLW at various stages of the chain, see Section 2.2.5.

[15] This is again an important meso-cause of FLW, see Section 2.2.5.

2.1.2 Harvesting and initial handling

Poor harvest scheduling and timing, as well as rough, careless handling of the produce, are key contributors to FLW along the chain.

For grain crops, such as maize, sorghum and groundnuts, overmaturity and delayed harvesting are reported to be major factors contributing to aflatoxin contamination (Farag, 2008; Lewis *et al.,* 2005). In some developing countries, farmers habitually leave cereals such as maize in the field upon maturity to dry because they lack facilities for drying. However, when the harvest season coincides with the second rains, as is the case in some countries, there is increased rotting and aflatoxin contamination, a major cause of food losses in cereals (Alakonya,Monda and Ajanga, 2008).

For manioc, a study in Cameroon (FAO 2014b) identified as a major cause of loss tubers being harvested too late, after having been "stored" in the field, getting lignified or eaten by rodents.

For fruits and vegetables, maturity at harvest is a major determinant of quality and shelf life of the produce, especially for highly perishable produce. However, farmers may be driven to harvest such crops prematurely due to poverty, urgent need for food and cash, or – as is often the case for banana – due to insecurity and fear of theft. Immature fruits are more prone to mechanical damage and shrivelling and have inferior eating qualities when ripened, such as high acidity and low sugar. Conversely, overmature fruits have a short shelf life and are often mealy with insipid flavour (Sivakumar, Jiand and Yahia, 2011). In both cases (immature and overmature), the fruits are highly susceptible to physiological disorders. Premature harvesting leads to reduced nutritional and economic value (Kader, 2008). Sometimes the produce may be totally lost as it may not be suitable for consumption (Kitinoja and Kader, 2003).

Harvesting techniques can also contribute to the losses. Multiple handling increases damage, especially for highly perishable commodities such as fruits and vegetables (FAO, 2013d). Farmers can also lack proper containers to pack the harvested produce during or immediately after harvest. For fruits, vegetables and root and tuber crops, mechanical damage during harvesting is a major factor contributing to losses and waste. The injured spots and tissues not only serve as entry points for pathogens but also increase water loss and ethylene generation, aggravating the problem.

Temperature management is key to maintenance of perishable produce quality as it is central to prevent other deteriorative processes such as microbial growth, softening and water loss leading to shrivelling. Failure to maintain a low temperature of produce immediately after harvest is a major contributor to spoilage at the subsequent stages of the value chain. Initial cooling of perishable foods such as fruits, vegetables, milk, meat, fish and mushrooms destined for distant markets (domestic or export) is critical for maintenance of quality. Therefore, storage in cold rooms or under shade immediately after harvest makes a significant difference in shelf life of the produce. Most growers in developing countries lack on-farm cold storage facilities or shade. As a result, the perishable produce is left in the open or kept under ambient room conditions.

The time of day when the produce is harvested has implications on the product temperature and efforts needed to lower it. Some producers harvest their produce during the hot hours of the day. Such produce is not only difficult to cool during storage but is more prone to faster deterioration (Kader, 2002).

For some root, bulb and tuber crops, such as potato, sweet potato and onion, curing[16] is known to extend the shelflife. However, most growers rush to market their produce immediately after maturity or harvest. Delays in marketing uncured crops result in high losses or waste due to water loss and decay (Kader, 2002).

High appearance standards may divert food that is perfect for human consumption into other uses that are less profitable (Stuart, 2009). For instance, 20 percent of the potatoes are sorted out in Swedish potato farms due to quality standards (Mattsson *et al*., 2001). Often the rejects/culls end up in processing/feed industries, hence not totally lost.

For other perishable food commodities such as meat, milk and fish significant losses are attributed to poor harvesting practices and lack of appropriate infrastructures for harvest and first handling

[16] For example, for potatoes, curing means placing them at a temperature of 7–15 degrees Celsius and high relative humidity (85–95 percent) for two weeks.

For fish significant losses at the harvesting stage partially result from using methods and gears that are not perfectly selective. This leads to capture of unsellable, unwanted and inedible products, which are subsequently discarded dead or debilitated and not used for any useful purpose. The volume of fish discards varies greatly between fisheries and within fisheries, with discard rates ranging from negligible in some small-scale coastal fisheries or, for instance in Atlantic herring fisheries, up to 70–90 percent for some demersal trawl fisheries. Global discard volumes are particularly challenging to estimate, and any global figure is prone to significant uncertainty (HLPE, 2014). The latest report published by FAO in 2005 on the issue has given an estimate of an 8 percent global discard rate of the world total capture fisheries, with a lower rate of 3.7 percent for small-scale fisheries (Kelleher, 2005). Gustavsson *et al.* (FAO, 2011) have calibrated their fish losses calculations using Kellerher's (2005) data in terms of discard rates per fishing gear, therefore leading to similar results. Poor initial conservation conditions on the boat after harvest and inappropriate handling practices have also been reported to lead to significant quality deterioration before landing (FAO, 2014bc).

For milk, major losses are mainly attributed to initial handling of milk, spillage, lack of appropriate milking equipment and poor sanitation during milking. The latter could result in contamination of the whole stock leading to massive losses among smallholder farmers. Causes of losses at farm level, especially among smallholder farmers, include mastitis or water adulteration, which lead to rejection at the collection centre or factory (FAO, 2014bc).

2.1.3 Storage

Within the post-harvest handling stages, food items can be stored from a few hours to several months depending on the product and storage conditions. Storage serves as a means to deal with time, enabling delayed marketing and consumption of the produce. This can only be realized if the storage conditions are optimized, otherwise there are significant losses. It should be noted, however, that even with the best storage conditions, the shelf life is dependent on the initial quality and storage stability resulting from decisions made at the earlier stages of the supply chain.

In developed countries, storage facilities are well established right from the production stage and throughout the supply chain. Cold storage coupled with advanced complementary post-harvest technologies (such as controlled atmosphere, 1-MCP) enables the supply chain actors to significantly extend the shelflife and marketing period for perishable foods. In this case, losses during storage could arise from a breakdown of the refrigeration systems, temperature abuse resulting in freezing or chilling injury. Overall, poor management of conditions (temperature, gas composition, relative humidity) may lead to deterioration or contamination of stored products, just as over storage periods, due to lack of transportation and other infrastructure requirements.

In developing countries, lack of proper storage facilities is a major cause of post-harvest losses (FAO, 2011a). A recent study (Liu, 2014) considers that storage is the most important cause of post-harvest losses for all types of food in China. Cold storage facilities are non-existent or inaccessible to the majority of smallholder farmers in sub-Saharan Africa. Highly perishable produce requires adequate storage facilities with well-maintained conditions, mainly temperature, relative humidity and gas composition. If infrastructure for initial storage is lacking, perishable produce can spoil within hours (Rolle, 2006; Stuart, 2009). Without storage facilities, growers and producers need to sell their production regardless of market price (not being able to wait for better price conditions), or leave the produce unharvested, or face the risk of a total loss, in the case of delayed collection by transporters, wholesale or retail stores.

Use of low quality containers, or misuse of containers, leading for example to injuries from puncture, vibration and compression, was a key factor identified by a WFLO post-harvest losses study that measured losses of 26 horticultural crops in four countries (WFLO, 2010), and simple practices such as using liners in rough containers (wood or baskets) or halving the size of huge containers (sacks or crates) were found to reduce damage and subsequent losses by up to 35 percent.

In some instances, however, due to technical limitations, decisions aimed at preserving quality result in the opposite of the desired goal. For example, while cold storage is recommended to preserve quality, storing and chilling sensitive products at very low temperatures result in chilling injury, ultimately leading to discard of the produce. Also, mixing products such as fruits, vegetables, milk and meat in a single cold room, as is typical of most wholesale and retail outlets in developing countries, may have a negative effect due to contamination or accelerated deterioration.

Suboptimal storage conditions often favour chemical and biochemical reactions that result in undesirable changes in colour, flavour, texture and nutritional value. Poor storage conditions also favour microbial growth and rotting of stored products, which are eventually discarded. For root and tuber crops, poor storage conditions result in greening and sprouting, both of which lower the quality and nutritional value of the crop (Stuart, 2009).

Several chemicals or treatments can be applied before or during storage to enhance the shelf-life of fruits and vegetables. Some of these treatments (e.g. sodium hypochlorite, acetic acid, irradiation, hot air/water immersion) are used to sanitize the produce and therefore reduce microbial damage, while others (e.g. 1-MCP) inhibit the effects of agents of deterioration such as ethylene. However, injudicious use of these treatments results in damage to the products or in residues that render the products unsafe. In some cases, unregulated chemicals have been used to enhance the shelf-life of perishables, thereby posing a health hazard. There are acceptable chemical methods such as the lacto peroxidase system (LP-system) for milk preservation, especially in rural areas where refrigeration facilities are non-existent (Ndambi *et al.,* 2008). However, unscrupulous traders often resort to other chemicals such as hydrogen peroxide and formalin, which may extend the shelf-life of the milk but are harmful to users. Often such milk is impounded by public health officers, resulting in high wastage.

Shelf stable foods such as grains can be stored for long periods if the storage conditions are optimized. Traditional storage practices adopted by smallholder farmers in developing countries protect stored grains from storage pests. However, some of the storage structures are rudimentary or poorly designed/constructed. Most farmers in sub-Saharan Africa still use traditional grain stores made of grass, wood and mud. These structures cannot guarantee protection against major storage pests such as rodents, insects, birds and fungal infections (Yusuf and He, 2011; Kankolongo, Hell and Nawa, 2009). In some cases, there are no storage facilities and farmers simply store the grains inside their house (Bett and Nguyo, 2007). Lack of storage, again, may lead to food loss and economic losses, as farmers needing to sell their grains soon after harvest due to lack of storage facilities create conditions of oversupply in the market, which attracts low prices. A few months later, the same farmers are forced to buy back their grains at a higher price.

Proper drying of the grains to a safe, low moisture content (<13 percent, with variations depending on the grain) is critical for proper storage. However, due to factors such as poor weather and lack of knowledge by the farmers, the grains are often improperly dried. Such grains are predisposed to pest damage and fungal growth (IFPRI, 2010). For example, in maize, losses attributed to post-harvest pests are estimated to be 30 percent. The major pests in this case are common weevil (*Sitophiluszeamis*) and the larger grain borer (*Prostephanustruncatus*), reported to cause 10–20 percent and 30–90 percent losses, respectively (Bett and Nguyo, 2007). The damage caused by these pests results in low nutritional value, high percentage germination (for seed grains), reduced weight and low market value (Yusuf and He, 2011).

In large-scale storage facilities in sub-Saharan Africa, standards of fumigation treatment to destroy insect infestation are generally too poor to kill all insects, which encourages insect resistance to the fumigant. Although the incidence of resistance has not been investigated extensively in sub-Saharan Africa, it is known for Morocco (Benhalima *et al.,* 2004).

2.1.4 Transport and logistics

Transport can be a major cause of FLW, by introducing a time span between production and consumption, of particular importance for fresh products, as well as additional risks of mechanical and heat injury.

In developed countries, transportation of the perishable foods in refrigerated trucks is standard practice, with mechanized and well-coordinated loading and offloading. Losses occur when the cooling system malfunctions during transport, the trucks break down or are involved in accidents. Sometimes losses occur when there are delays in loading docks where no cooling is provided.

Conversely, in developing countries, lack of proper transportation vehicles, poor roads and poor/inefficient logistical management hinder proper conservation of perishable commodities during transport (Rolle, 2006). It is not uncommon to find highly perishable produce being transported in open, unrefrigerated trucks. Additionally, loading and off-loading of fruits and vegetables are done manually by casual labourers who handle the products roughly, causing extensive mechanical injury. Usually the fragile products are stuffed into the truck to accommodate more volume without paying much attention to mechanical damage caused to the products or predisposure to deteriorative processes (Kader, 2002).

In most cases, these products are poorly packed/packaged for transport. Some transporters use sacks, or polythene bags or simply load the “naked” products directly onto the trucks, leading to compression damage during transport. The poor state of roads, especially in rural areas where most of the production occurs, further aggravates the losses during transportation. The status of the roads worsens during the rainy season and it is common to see trucks ferrying perishable products breaking down or getting stuck in the mud for days. In such instances, the perishable products get spoiled and never reach their destination. In developing countries, it is estimated that post-harvest losses of fruits and vegetables can range from 35 to 50 percent annually due to poor infrastructure (IMechE, 2013).

Fish is a very perishable food and hence susceptible to high post-harvest losses after landing, either in quantity or quality, due to post-harvest handling during transport, storage, processing, on the way to markets or in markets waiting to be sold (HLPE, 2014). Similarly, the logistics-related loss in dairy products is significant (more than 10 percent) in developing countries. Inability to market milk products during the rainy season, lack of proper transportation and cold chain during the hot season, an erratic power supply to milk processors and coolers are some of the causes of losses in dairy products.

Logistics-related risks also occur in the transportation of food-producing animals. Transport of livestock is known to be stressful and injurious, which can lead to poor animal welfare and production loss. For example, in the United States of America about 80 000 pigs die per year during transport (Greger, 2007). A case study in Ghana indicated that more than 16 percent of expected income is lost due to occurrence of death and sickness or injuries of cattle during transport from farm to cattle market and abattoir (Frimpong *et al.,* 2012). A similar case study in central Ethiopia (Bulitta, Gebresenbet an Bosona,2012) indicated that over 45 percent of animals were affected (either stolen, died or injured) during cattle transport from the farm to the central market.

A large problem that occurs at the distribution stage is that of rejected shipments. Imported products are subjected to testing at the point of exit or entry to check adherence to phytosanitary, veterinary and food safety regulations. This testing process often delays shipment and considerably reduces the shelf-life of the perishable products. In some cases, shipments are rejected on account of failing to meet regulatory requirements or market standards set by the target markets. In such instances, the whole shipment is dumped/destroyed if an alternative buyer cannot be found in time.

2.1.5 Processing and packaging

For many products, transformation can be a way to reduce FLW and increase shelf life, particularly for perishable products.

In most developing countries, there is a general lack or inadequacy of processing facilities. The processing industries often lack capacity to process the volumes delivered. The situation is aggravated by seasonality of some of the processed products. A good example is mango, which is seasonal in most tropical countries. In Kenya, the processors are overwhelmed during the peak season (December to March) when there is an oversupply of mango fruits. As a result, high volumes of mangos delivered to the processors go to landfills due to the limited capacity of the processing plants. Consequently, the farmers or traders who deliver the fruits to these factories incur high losses from transporting the fruits to the factories only for the fruits to be discarded or bought at very low prices.

The situation is similar for milk production, which is “seasonal”, with high volumes during the wet season when there is an abundance of livestock forage crops. During the high season when there is an oversupply of milk, much of it can be lost if the processors can only handle limited volumes.

Food losses at the processing stage are mainly due to technical malfunctions and inefficiencies. Errors during processing often lead to defects in the end product, such as wrong size, weight, shape, appearance or damaged packaging. Although these defects have no bearing on the safety or quality of the product, processed food can be discarded for not adhering to set standards.

For animal products, contamination during processing is a major cause of losses. The contamination may originate from the processing unit not being properly cleaned and sanitized from previous operations or originate from part of the produce that contaminates the whole production batch. Importantly, once a product is declared unfit for human consumption, the entire production batch is lost. Another source of loss, especially in horticultural commodities, is excessive trimming to attain a certain shape or size. Trimmings (from produce such as carrots, cabbages and lettuce), although perfectly fit and safe for human consumption, are usually discarded.

Lack of proper process management and of standards to ensure food safety and quality can result in some of the processed products being unsafe and nutritionally poor. For some fruits and vegetables, blanching is done prior to drying or freezing to arrest enzymatic activity. Failure to blanch often results in off-flavour and discoloration of the processed products, which may be discarded. Failure to optimize the blanching conditions (such as duration and temperature) often results in products of inferior aesthetic and nutritional quality, which may be rejected by the consumers.

Packaging can be an important element to extend shelf life and prevent food losses and waste (FAO, 2011a). While reduction of packaging could be an important element of waste policies, it could have the unintended consequence of increasing the amount of food waste.

2.1.6 Retail

The retailers influence the activities of supply chains as they dictate the quality of the produce to be supplied and displayed in their outlets. Conditions within the retail outlet (temperature, relative humidity, lighting, gas composition, etc.) and handling practices have an effect on quality, shelf-life and acceptability of the product.

High losses at the retail stage occur in perishable commodities such as fruits and vegetables, fish and seafood, meat, dairy products, baked foods and cooked foods. In the United States of America alone, it was estimated that the in-store food losses were 10 percent of the total food supply (Buzby, Wells and Hyman, 2014). In Norway, according to the Format[17] project (see Chapter 4) retail stage represents 18 percent of the FLW.

Losses at the retail stage are even higher in situations where measures such as protective packaging, temperature and humidity control, and proper display to minimize handling by buyers, are not in place.

In many open-air markets in developing countries, the traders sprinkle unclean water onto vegetables and fruits to minimize wilting and shrivelling under the hot sun. Such practices, which are aimed at slowing down deterioration, result in unsafe foods that are shunned by buyers and may end up being discarded.

Some of the factors (drivers) seen to contribute significantly to the high losses at the retail stage include inappropriate product display and efforts to anticipate expectations of customers, including for convenience.

In most retail outlets, piles of fresh-looking produce on display are seen as a means to attract buyers, who then have the luxury to choose by rummaging through the pile. Products such as fruits at different ripening stages are piled together to give the buyer a choice. This has three effects that contribute to high losses at this stage: the produce at the bottom of the pile is damaged by the weight of the produce on top, piling fruits at different ripening stages shortens the shelf life of the produce that would otherwise have a longer shelf life because of the different ethylene production and respiration rates and, as the buyers rummage through the piles, they injure the other produce. Besides, the products of advanced ripening stages are more delicate and, when they are piled together with less-ripe products, they suffer more mechanical injury.

The store-owners seek to maintain a variety of products displayed in large volumes that are replenished regularly to fill the shelves for the consumer's satisfaction. When retailers mix different expiry dates for the same product, close-by expiry dates are ignored by the consumers, who prefer the "fresher/newer" products (SEPA, 2008).

The tendency to propose homogenous and "perfect" products (in terms of colour, shape, size, freedom from blemishes) have led most retailers to set high standards for products. It is a major cause of loss, as failure to adhere to these standards by the producers results in rejection at delivery or culling of the displayed products.

Most retailers have ventured into fresh-cut (fruits and vegetables) and ready-made fresh or cooked foods to meet the demand of the consumers. It can be an opportunity to valorize produce that failed to comply with cosmetic standards but ready-made products are also more prone to spoilage – if they remain unsold at the end of the day, they are just discarded. Growth in fresh-cut produce has been

[17] http://www.nhomatogdrikke.no/getfile.php/ForMat/Engelsk%20presentasjon%20ForMat.pdf

stimulated by consumer demand for fresh, healthy, convenient foods that are safe and nutritious. The fresh-cut products are prone to discoloration, rotting and dehydration due to damaged and exposed tissues and lack of protective skin. Deterioration of the fresh-cut produce is aggravated by poor packaging and temperature management. Even in developed countries, in conditions of proper packaging and cold chain, discards of fresh-cut products are significantly high, even if packaging can sometimes extend shelf life, such as with bagged salads.

In some cases, retailers may use unregulated chemicals or overuse regulated chemicals to maintain freshness of the produce to attract consumers. Injudicious use of such chemicals on foods, which may be impounded by public health officers, contributes to food discards. Conversely when such practices go unnoticed, there are serious food-safety concerns.

Important causes of FLW at retail stage (and also for suppliers) are linked to shelf life, variability of demand as well as increasing demand for fresh products (Mena, Adenso-Diaz and Yurt, 2011). At the upstream end of the supply chain, growers grow to semi-formal demand forecasts by retailers (and forecasts made by the suppliers themselves). Final, confirmed orders are often made only days before delivery. In other cases, retail stores impose strict conditions on the growers, such as quantity and quality specifications. This sometimes prompts the growers to overplant to ensure that they fulfil the buyer's conditions. The extra produce is often discarded or sold at a lower price to alternative buyers. Sometimes, the stores make last minute changes in the orders (often reducing the quantities) which results in FLW of the extra produce (Stuart, 2009; UK Competition Commission, 2008).

Finally, a common, self-imposed practice among food businesses – the so-called "rule of the one-third" - according to which processed foods must reach the suppliers in up to one-third of their shelf-life time is also a cause of FLW. Its primary intention is to allow consumers to have a wide choice of very fresh products relatively far from the expiration date. But if products fail to be delivered by the first third of their shelf life, many retailers will reject the delivery and return the items to producers, leading to discard of safe food (NRDC, 2013).

2.1.7 Consumption

The consumer waste problem is mainly an issue in developed countries (see Figure 2). However, emerging economies increasingly face a similar challenge: income growth and demographic changes over the past 20 years have brought a change of eating habits with an explosion in the consumption of processed foods, together with a relative convergence of diets (consumption of meat, chicken and dairy per capita), the emergence of obesity problems, rising rapidly even in some cases among the poorest part of the population,[18] and average level of consumer waste increasing with household wealth. For instance in China, consumer waste, which is mainly linked to restaurants and canteens, is increasing, driven by growing affluence, urbanization, and the growth of the restaurant and catering sector (Liu, 2014).

Most of the studies on consumer food waste and discards have been conducted in the United States of America and Europe. The WRAP has been particularly active in the United Kingdom. Such a prevalence of studies in developed countries is understandable as consumer food waste is particularly important and of concern in those countries. However, considering the role of social and cultural drivers in food consumption and attitudes towards food, the results of these studies have to be taken with caution if they are to be extended to other cultural areas, both in the developed and developing world.

Consumer food waste is challenging to measure: consumers generally underestimate their own waste in surveys. In Spain, consumers estimated that they wasted 4 percent of food, while the actual number was 18 percent (HISPACOOP, 2012). Sample analysis is a more reliable method, although a much more costly one and also with specific methodological challenges (Lebersoger and Schneider, 2011). A combination of the two methods can be the most efficient (Hanssen and Møller, 2013).

Data available on consumer food waste in two countries, the United States of America (USA) in 2010 (Buzby, Wells and Hyman, 2014) and the United Kingdom (UK) in 2009 (WRAP, 2009) show an issue of substantial proportions: in the USA, food waste totalled USD370 per capita, and in the UK USD580/year equivalent per household. This amounted to 9 percent of the average value spent on

[18] For instance, in the case of Brazil, according to anthropometric the incidence of obesity in 2003 was of 18.8 percent among the non-poor adult population (resp. 3.6 percent among the poor adult population). In 2009, these rates increased to 24.7 percent and 13.6 percent, respectively (Belik, 2012).

food per consumer, and 1 percent of disposable income in the USA, and to 15 percent of expenditure on food and drink of UK households.

From the FAO (2011a) figures at global level, most of the waste in households is fruits and vegetables (39 percent) followed by cereals (33 percent), with important regional differences.

According to a survey conducted by WRAP (2009) for households in the UK, 41 percent of the waste occurs because too much was cooked or served, and 54 percent of waste is because the food was not used in time. This later reason has to be interpreted with caution as studies (Evans, 2011a, b) show that consumers tend to wait until the food cannot be consumed, or until its "use-by" or "best-before date" is passed, before throwing it away (see Section 2.2.4). It thus often hides more complex reasons.

Among causes of FLW at consumer level are often mentioned (WRAP, 2009; HISPACOOP, 2012; Baptista *et al*., 2012):

- poor planning of purchases often leading to buying more than is needed – impulsive or advance purchasing of food that is not required immediately;
- discarding food due to confusion over "best-before" and "use-by" dates (see Section 2.2.4);
- poor storage or stock management in the home;
- excess portions prepared and not eaten;
- poor food preparation techniques often leading to less food being eaten or food quality losses and waste (FQLW and nutritional content decrease) due to the preparation method. Lack of knowledge on how to consume/use food more efficiently, e.g. use of the leftovers on other recipes instead of discarding.

Four household criteria are often identified as having an impact on the level of waste in households in developed countries: household size and composition, household income, household demographics and household culture (Parfitt, Barthel and Macnaughton, 2010). Households with fewer residents could discard more because the parts purchased and prepared are typically larger than the consumption capacity; households with higher incomes discard more – consistent with their greater food consumption. It turns out also that there is often a larger discard in households with a greater presence of adolescents and young people and, finally, there is an influence of the cultural environment on the level of discard. These broad tendencies are quite variable, according to contexts, with important national and regional differences (HISPACOOP, 2012).

Segrè (2013), from a cluster analysis of an open survey distinguishes seven types of causes of consumer attitudes leading to waste, linked to food preferences, food consumption habits, and to different representations of the reasons why they waste.

Evans (2011a, b), through ethnographic analysis of social and material contexts of everyday food waste practices in some English households underlines the need to consider the waste as a consequence of the ways domestic practices are socially and materially organized. He shows how household provisioning routines, time management, accounting for family tastes and food safety concerns can drive day-to-day waste, in spite of awareness to it. Such analysis invites greater attention to the links between food consumption habits, including food provisioning, and food waste. It also shows that food waste often results from complex and contradictory demands of everyday life (Quested *et al.,* 2013), including time constraints (Soyeux, 2010).

Another element that probably plays an important role, although less studied, is buying habits. Buying less often and in greater quantities, could increase waste, as the possibility of products losing quality is greater and it is more likely that the product will spoil than when consumer habits or financial constraints lead to purchase of supplies for the same day or smaller periods of time.

A study on bread waste in Iran (Shahnoushi *et al*., 2013), where it is subsidized, has confirmed some general causes for waste, mainly low price, the existence of a market for stale bread to be used as feed for livestock, quality issues, and, linked to it, the attachment of consumers to very fresh bread. It also showed that there are other important factors driving the behaviour leading to more waste. In particular having to walk to the bakery, going more often to the bakery and an increased waiting time at the bakery, all these factors increase the probability of a household to waste more on bread.

A study conducted in Sweden (Williams *et al.,* 2012) suggests that packaging and its functions relate to 20 to 25 percent of food waste. Portioning and pack size are identified as major drivers related to food waste, as consumers tend to buy large packs and bulk offers, to maximize value for money

(FUSIONS, 2014). In these cases the food waste generated at the household can find its root cause at retail level. Some consumers who wish to buy just small quantities of a product are forced to buy more than they need because of the package size (HISPACOOP 2012). Advertising campaigns prompting impulse buying, product promotions and bulk discount such as “three-for-two” or "economic packages" on sale in supermarkets induce waste because, once opened, the tendency is that they spoil before being consumed. In certain countries such as the United Kingdom (WRAP, 2011a), promotions make up a third of grocery spend, with an increasing trend. WRAP has conducted research to acquire a basis for definitive quantitative data related to portion size in household settings. The first aim was to identify how much the general public is dissatisfied with the size of portions available on the market for certain key products and why they are dissatisfied. The second was to get understanding of what might be the demand for alternative portion sizes. Around one-third of respondents have had issues with portion sizes, the vast majority of those complaining that packs were too large for their needs. Those in smaller households were more likely to register dissatisfaction with existing pack sizes. Research suggested that consumers are not necessarily averse to paying a little more per unit of volume/weight to avoid being left with unnecessary surplus (WRAP, 2008b).

Food is also used as a symbol of prosperity, hence a larger quantity of food, and therefore a larger propensity to waste, is caused by people from higher socio-economic groups to provide variety and show prodigality (IMechE, 2013). Food discards can also be significant in restaurants and official events. The recent “Empty Plate” campaign in China draws attention to the food waste in banquets offered to or provided by government officials (BBC, 2013).

In school canteens and restaurants, the existence of a fixed price buffet (eat as much as you can), supersized portions and refills of soft drinks promote obesity and waste (Lipinski *et al.,* 2013). Tristram Stuart (2009) estimated that “24 to 35% of school lunches end up in the bin” in the UK. In recent research on middle-school students of Boston conducted by Cohen *et al.* (2013) in the United States of America demonstrated that, measured in calories, on average, students discarded roughly 19 percent of their entrées, 47 percent of their fruit, 25 percent of their milk and 73 percent of their vegetables.

A recent study (Silvennoinen *et al.,* 2012), in Finland, gives more insight on FLW in the restaurant and catering sector. Twenty percent of all food handled in restaurants and catering is wasted, with very clear differences between types of restaurants. Self-serving buffets have the biggest total waste (24 percent) with the biggest part of it (17 percent) being service waste, too much cooked food. Fast foods have the lowest total waste (7 percent). Kitchen waste is the lowest in schools and fast foods (2 percent), the highest in restaurants and day care centers (6 percent). Service waste is the lowest in restaurants (5 percent). Leftovers are the lowest in fast foods (3 percent) and the highest in restaurants (7 percent) and hospitals. The study concluded that planning, good management and documenting food waste data could considerably reduce FLW.

2.2 Meso-causes of food losses and waste

The previous section has reviewed causes of FLW by stages of the food chain where they take place. These were mostly micro-causes. Rarely a loss or a waste appearing at one stage of the chain is solely dependent on one specific micro-cause. As we have proposed in the introduction of this chapter, there is in fact a “hierarchy” of causes, whereby causes can be found at micro-, meso- and macro-level.

For instance, losses due to bad management of temperature happen at every stage of the chain, owing to lack of equipment and/or bad practices. These are indirectly favoured by lack of support from collective actors or other actors in the food chain. Ultimately, they can be caused by a lack of general infrastructure and storing capacities, electricity availability or costs and training.

Several meso-causes can add-up to each other to explain FLW for one product, as the case of the tomato supply chain in Cameroon shows (see Box 4).

This section describes some meso-level causes, such as: lack of support for actors for investment and improvement of practices (2.2.1), lack of adequate infrastructure (2.2.2), lack of coordination among actors (2.2.3), confusion about date labelling (2.2.4).

Box 4 Meso-causes along the tomato supply chain in Cameroon

FAO (2014c) has analysed causes of FLW along tomato supply chains in Cameroon. Tomato is consumed almost every day, fresh. It is produced mainly by small family farmers. There is no tomato processing in Cameroon. Tomato is a particularly fragile produce. Following a survey and field studies main causes of FLW post-harvest have been identified: handling, transport including bad state of the roads, lack of appropriate packaging, lack of adequate storage, lack of coordination between supply and demand. These causes drive important FLW and especially high FQLW causing important economic losses. For instance, in a load of tomatoes transported from Mbouda to Douala (312 km) the proportion of good quality tomatoes has decreased by more than 10 percent. Among the reasons for such FQLW figure the fact that many tomatoes are harvested to ripe and also that the load contained in the beginning tomatoes already spoiled which spoiled good fruits. In fact, there is no incentive for the producer to sort out its produce before selling it.

The study concludes that the weak organization of the sector, which results in bad coordination between supply and demand as well as bad transport conditions, lack of infrastructures, lack of adequate intermediate packaging, lack of training of actors are main causes of FLW, aggravated by insufficient road infrastructures.

Source: FAO (2014b)

2.2.1 Lack of support to actors for investments and good practices

All along the food chain, from the producer to the consumer, most of the micro-causes of FLW can be linked to lack of investment and/ or lack of implementation of good practices.

In the food sector in general, many actors are very small and face challenges to invest. Lack of investments often results from lack of access to finance and credit. In rural areas of developing countries, credit constraint is one of the primary bottlenecks in investment towards adoption of technologies to reduce food loss and waste in the whole food chain (HLPE, 2013b). Although microfinance programmes and community credit have advanced greatly in recent years, these cover only a small part of rural finance. Lack of access to formal rural credit can be as high as 80 percent in India, 85 percent in China according to Tang, Guang and Jin (2010) and around 40 percent in Peru, Honduras and Nicaragua (World Bank, 2007). Data collected by Doligez *et al.* (2010) show that in the past decade more than half of the African producers (except South Africa) had no access to credit, even for informal credit schemes.

Lack of implementation of good practices at different stages of the food chain can be due to the lack of initial and continuous training, the lack of collective organization at each point of the food chain, the lack of integration and coordination along the food chain (see Section 2.2.3), the lack of extension services, and also the lack of appropriate policies (see Section 2.3.2).

Moreover, at many stages that are key to the preservation of the quality of the product and of its conservation capacity, such as harvesting, loading and unloading of produce, the often harsh tasks are accomplished by low-paid, underqualified workers, with no incentive to take care of the product, or even disincentives as often pay is proportional to the mass of product handled, which can lead to too rough and too rushed handling (FAO, 2014c). These jobs are often short-term, which does not give them the opportunity to improve their practices.

2.2.2 Lack of private and public infrastructure for well-functioning food chains

Lack of infrastructure or infrastructure not adapted to food chain conditions is a reason behind many micro-causes of FLW.

One can distinguish private food chain infrastructures, which include for instance storage, cold chains and processing facilities and public infrastructures, often to support and facilitate access to inputs (including energy) logistics, transport and marketing (HLPE, 2013b).

Infrastructure-related FLW can happen when, such as for fruits and vegetables in India, production significantly increases without the relevant development of infrastructure, such as cool and cold chambers, cold transportation chain, or processing and preservation techniques. In those cases, increased production comes with a – more than proportional – increase of losses.

Market infrastructure

Efficient markets including but not limited to physical infrastructure are essential to reduce the time between production and consumption, which is an important factor to limit FLW. The quality of the physical infrastructure in wholesale and retail markets (e.g. off-loading areas, handling facilities, display, storage, ambient conditions, temperature, etc.) is also crucial to reduce FLW on the markets and down the food chain.

Storage infrastructure along the chain

In many low-income countries, there is considerable food loss due to lack of storage capacity and poor storage conditions as well as lack of capacity to transport the produce to processing plants or markets immediately after harvesting, as noted by numerous studies, such as FAO (2014c). There are also too few wholesale, supermarket and retail facilities providing suitable storage and sales conditions for food products. Wholesale and retail markets in developing countries are often small, overcrowded and lack cooling equipment and proper sanitary conditions (Kader, 2005).

Cold chain infrastructure

Availability and efficient use of the cold chain significantly affect FLW. Temperature control is the single most important factor in food preservation, especially for perishable commodities. It is estimated that the rate of deterioration of perishables increases two- to three-fold with every 10 °C increase in temperature within the commodity's physiological temperature range. Mittal (2007) reported that about 30 percent of the fruits and vegetables grown in India are lost or wasted annually due to gaps in the cold chain. Fonseca and Njie (2009) found that the lack of capacity of the cold chain is the main reason for post-harvest losses in Latin America and Caribbean countries. Therefore, maintaining low produce temperature right from harvest to retail (cold chain) is of paramount importance in quality preservation.

In most countries of sub Saharan Africa, use of cold chain for meat conservation encounters challenges, including low number of refrigerated trucks, lack of cold storage in consumption areas, apart from some supermarkets, high cost and unreliability of electricity supply, lack of material as well as of specialized human resources to manage them (FAO & IIF, 2014). In Uganda there is an important potential demand for the use of cold chain, for meat, fruits and vegetables. There are however important constraints to the development of the sector, including, in addition to those mentioned above, difficulties to find spare parts for materials often bought second hand in Europe, high costs and a lack of organization of the sector, with many installations dedicated to single enterprises (FAO & IIF, 2014), often for export.

The absence of cold chain infrastructure (including on-farm cold rooms, reliable power supply, refrigerated transport facilities and equipment), enabling all food supply chain actors to ensure low temperature conditions for produce from production to retail, is a major cause of FLW. This is less the case in industrialized countries, where functional and well-developed cold chains exist, than in many developing countries, where the cold chain infrastructure is either non-existent, difficult for actors to access, poorly maintained or poorly utilized. The cost of providing the cold chain per tonne of produce depends on energy costs plus utilization and efficiency of the facilities. In developing countries, the need for cold chains grows rapidly, and there are challenges for many companies to bear the sometimes significant investment in cold chain logistics, such as the example of Beijing shows (Lan and Tian, 2013).

Processing infrastructure

In many situations the food processing industry does not have enough capacity to process and preserve fresh farm produce in order to meet the demand. Part of the problem stems from the seasonality of production and the cost of investing in processing facilities that will not be used year-round (FAO, 2011a). There is also a lack of packaging facilities (FAO, 2011b). Choudhury (2006) highlights high loss rates associated with a lack of packing houses in India, with fresh fruit and vegetables generally packed in the field and some even transported without transit packaging.

2.2.3 Lack of integrated food chain approaches and management

It is important not to confuse "where" a specific loss or waste is occurring with its "cause" (micro, meso or macro). Losses and waste at one stage of the food chain can have their cause at another stage. For instance, lack of care in the manipulation of fruits in the very early stages, harvest and packaging, which in turn can be related to poor work conditions, can reduce their shelf life and cause retail-level loss or consumer waste later on. Conversely, fruits can be left to rot in the field because of a retailer's decision to lower its buying price or interrupt a contract. Reducing FLW thus requires identifying their ultimate cause(s) and often an integrated perspective along the food chain.

Without a well-functioning integrated food chain, food losses are exacerbated, especially in low-income countries. One reason for losses in the food chain is the increasing distance between the places where food is produced and where it is consumed. Apart from farmers, transporters, storekeepers, the food processing industry, shopkeepers and supermarkets, among others, are involved. We therefore need to look at the stakeholders and drivers in various segments of the food chain and to what extent the interests either coincide or are at odds across major groups. Enhancing efficiency in one part of the chain, e.g. in production, can be nullified if losses and wastage occur, or increase, in other parts of the chain.

Retailers are ultimately the interface between production and consumption. They play a crucial role, particularly in countries where the retailing sector is oriented towards large-scale enterprises. How the retail sector performs within the organization of the food chain can be determinant for FLW. For instance, a small number of large retailers in the United Kingdom exercise market power over the 7 000 suppliers within the sector. To avoid being "de-listed", food manufacturers will often overproduce in case extra quantities are required at short notice. For manufacturers of supermarkets' own brands, packaged surplus production cannot be sold elsewhere and becomes lost (C-Tech, 2004).

Parfitt, Barthel and Macnaughton (2010) have identified factors that can lead to food losses and waste in the food supply chain, many of which are linked to contractual practices:

- payment terms discouraging small growers;
- retailers' product quality standards deterring smallholders from supplying produce to the market;
- high contractual penalties for partial or total non-delivery of orders by suppliers;
- product take-back clauses in supplier contracts allowing retailers to return a product to the suppliers once a residual shelf life has been reached;
- often poor demand forecasting and replenishment systems and a lack of FSC transparency; and
- difficulties inherent in transitioning from trading systems previously driven by spot market prices towards long-term contracts.

Lack of horizontal and vertical linkages contributes to inefficiencies in the food supply chain leading to FLW. This impedes the organization of collective investments and actions that can enable access to credit to finance production and post-harvest handling facilities such as cold rooms, drying equipment and processing units (HLPE, 2013b). The lack of effective communication, infrastructure and information flow also causes logistics risks and mismatches between supply and demand in the food supply chain.

2.2.4 Confusion around food date labelling

With an increasing trend for consumption of processed foods, with urbanization, the lengthening of the food chains and the weakening of personal links between producers and consumers, consumers rely increasingly on date labels as a substitute to direct knowledge and advice on the freshness and shelf life of products.

Many kinds of date labels coexist, some of them not intended for consumers but for retailers for their management of stock, other directed to consumers, either to protect the consumer's experience of a product and to safeguard its reputation, or to indicate a date after which it can no longer be eaten for safety reasons. Consumers get lost in this multitude of date labels (see Box 5).

Various studies in the United States of America (NRDC, 2013), Europe (Bio Intelligence Service, 2010), in the United Kingdom (WRAP, 2011b) and in Spain (HISPACOOP, 2012) have underlined that food date labelling, and confusion about it, are a major, indirect cause of FLW at retail and consumer levels, as consumers tend to assume that dates are linked to food safety when they are in reality more often grounded on food quality.

According to a national survey (GfK, 2009) confusion over date labelling and consumer misunderstanding of date labels account for a substantial part of household food waste in the United Kingdom.

Furthermore, date labelling is also a major cause of FLW and of economic loss at retail level as retailers often anticipate dates to preserve their good image (MAGRAMA, 2013; NRDC, 2013). In Europe there are two types of legally required date marks (Directive 2000/13/EC) addressed to consumers: "*best-before*", which relates to food quality and indicates the "date until which the food stuff retains its specific properties when properly stored" and "*use-by*" which relates to food safety, for "food stuffs which, from the microbiological point of view, are highly perishable and are therefore likely after a short period to constitute an immediate danger to human health". A product with a "*use-by*" date cannot be sold after that date. Setting the appropriate durability indication and date mark, as well as storage instructions, is of the responsibility of the manufacturer, packer or EU seller.

In the United States of America there is no general federal regulation for food date labelling (NRDC, 2013). The Food and Drug Administration has issued explicit date labelling requirements only for infant formula products. The USDA has technical requirements on how the dates should be displayed on some USDA-regulated food products (meat, poultry and certain egg products) *in case the date is displayed voluntarily or in case a state law exists* to make such display compulsory. The National Conference on Weights and Measures (NCWM) has issued a voluntary guidance. This guidance sets "*sell-by*" as the label date that jurisdictions should require for pre-packaged perishable foods and "*best-if-used-by*" as the date that should be required for semi-perishable or long-shelf-life foods. The model regulations allow all foods to be sold after their label dates, provided that they are of good quality and that perishable foods are clearly marked as being past-date. It also includes guidance for properly calculating the label date and for expressing the date on packaging. However, according to NRDC (2013), only a minority of US states (8) have regulations adopting it.

As dates such as "sell-by", intended for retailers, increase confusion for consumers, some recommend making them less visible to consumers (DEFRA, 2011). The confusion also points to the need to establish a coherent and uniform consumer-oriented dating system, with a clear distinction between quality based and safety based date labels.

Lastly, date labelling is only one dimension affecting the quality and safety of the product, as the respect of proper adapted conditions of conservation is also paramount for the food safety and nutritional quality of products.

Box 5 A multitude of different date labels

Codex Alimentarius, in its General Standard for the labelling of prepackaged food (1985) defines the following categories of labelling dates.

"Date of Manufacture" means the date on which the food becomes the product as described.

"Date of Packaging" means the date on which the food is placed in the immediate container in which it will be ultimately sold.

"Sell-by Date" means the last date of offer for sale to the consumer after which there remains a reasonable storage period in the home.

"Date of Minimum Durability" ("best before") means the date that signifies the end of the period under any stated storage conditions during which the product will remain fully marketable and will retain any specific qualities for which tacit or express claims have been made. However, beyond the date the food may still be perfectly satisfactory.

"Use-by Date" (Recommended Last Consumption Date, Expiration Date) means the date that signifies the end of the estimated period under any stated storage conditions, after which the product probably will not have the quality attributes normally expected by the consumers. After this date, the food should not be regarded as marketable.

These Codex categories are voluntary tools at international level, unevenly followed by countries. For example, in the European Union, the "use-by" criteria relates to food safety, whereas in other regions it is linked to a manufacturer's quality criteria. Also manufacturers use other kinds of appellations for dates, often not clearly defined (such as "display until" or "freeze by", etc.), which induces more confusion.

2.3 Macro-level causes of FLW

Micro- and meso-level causes can be driven by broader macro-causes (Figure 5). Macro-level causes include those that are linked to the policy and regulatory environments, as well as systemic causes that can appear at various levels.

2.3.1 Impact of policies, laws and regulations on FLW

The ability of the actors of the food chain to reduce food losses and waste depends on the surrounding policy and regulatory framework. Some regulations have an impact on FLW, such as policies that may help or hinder surplus food being redistributed or used in animal feed, policies or bans on fish discards, food hygiene regulations, food labelling and packaging regulations, waste regulation and policies (House of Lords, 2014). Other regulations might not have a direct impact on food losses and waste, but on the potential to use them as feed or energy.

Food safety schemes

The manufacture of safe food is the responsibility of everyone in the food chain and food factory, from the operative on the conveyor belt to higher management. The production of safe food requires the following:

- control at source;
- product design and process control;
- good hygienic practices during production, processing, handling and distribution, storage, sale, preparation and use;
- preventive approach as effectiveness of microbial end-product testing is limited.

Food safety rules and regulation are generally linked to good practices for conservation. They include the application of the Hazard Analysis and Critical Control Point (HACCP) approaches to biological, chemical and physical hazards in production processes. When they are well designed they contribute to reduce FLW and to improve the quality of shelf life. On the other hand, as the example of date labelling shows (see Section 2.2.3), they can be a cause of FLW.

Food discards out of food-safety concerns are important in medium-/high-income countries. In Europe, private regulations have been identified as major reasons for throwing away food in the catering business due to strict hygiene rules and wide safety margins (Waarst *et al.,* 2001). Fonseca and Njie (2009) report that the rejection of fruit and vegetables from Latin America and Caribbean countries into the United States of America is mainly owing to food-safety concerns. Food regulations can be applied in ways that remove food that is still safe for human consumption from the food supply chain (FAO, 2013d).

The rapid globalization of food production and trade has increased the potential likelihood of international incidents involving contaminated food. Food safety authorities worldwide have acknowledged that ensuring food safety must not only be tackled at the national level but also through closer linkages among food safety authorities at the international level. Lack of coordination of policies at regional level can be an important cause of FLW (FAO, 2013d).

Agricultural investment policies, including training and extension

Most governments are taking the necessary steps to increase food production and food security for their populations. However, the efforts to increase food production must be coupled with equally important measures to ensure that the increased food reaches the end-users (processors, exporters, consumers), and that solutions are adapted and affordable to local conditions. Poor agricultural development planning can result in some of the additional food produced ending up being lost or wasted, because of unadapted infrastructural development, poor roads, lack of bulk storage facilities and lack of processing (transformation) industries.

All of this requires government planning and investment along with agricultural development investments, investment in better production and immediate post-harvest handling practices. In this context, extension services are key, as well as local human and infrastructural research capacities. Private sector investors interested in agricultural development are sometimes deterred by government policies/regulations that render investment unattractive.

Animal feed regulations

Some countries, or regions, such as the EU with the animal by-product regulation, have placed bans on feeding animals with catering discards that have been in contact with animal by-products. This affects redirecting much of the "mixed" food waste from this broad sector to animals, as it is often impossible to sort between products having been or not in touch with animal by-products. In the EU, the bovine spongiform encephalopathy crisis led to a prohibition of processed animal proteins (PAP) as feed to most farm animals. The ban on feeding non-ruminant PAP to fish was lifted in 2013. While these restrictions would not affect food losses and waste per se, they pose constraints on what usage or valorization can be made with the losses and waste.

Waste disposal policies

Finally, waste policies and practices do impact FLW. Availability of separate collection of food waste from mixed waste is a key step to avoid food waste being ultimately disposed of, but valorized, for example as compost, or in anaerobic digestors. Most countries have pricing schemes for waste recollection and landfill disposal, and these are also incentives to reduce waste overall, though they might not distinguish food from other waste. Some countries have gone as far as putting a ban on landfills.

2.3.2 Systemic causes

Systemic causes are those that favour the emergence of all the other causes of FLW, including micro- and meso-causes and, in the end, they can be a major reason for the global extent of FLW.

The systemic causes of food losses and waste differ in low-income and medium-/high-income countries. In low-income countries, they are mainly linked to financial, managerial and technical limitations in harvesting techniques, limited storage and cooling facilities in adverse climatic conditions, lack of infrastructure, packaging, transport, logistics, and marketing systems. In medium-/high-income countries, FLW can happen at the same stages, but for different reasons: mainly relating to a lack of coordination among different actors in the supply chain, and to consumer behaviour, as consumers can afford the "luxury" of wasting food, or the exigencies in aesthetic or other standards leading to the discard of food. A great part of losses at harvest stage in industrialized countries is partially attributable to the downstream of the food chain and to the consumption system or.

Among systemic causes figure discrepancies between technologies promoted at national or food chain level and the actual capacities and conditions, including logistics and transport. Others include, for instance, lack of or partial implementation of food-safety rules and practices, including prevention, monitoring and control. Systemic causes also include lack of investment, policies and institutions, or inappropriate (or missing) policy or regulatory framework to facilitate coordination of actors (including securing contractual relations), their investments and the adoption of good practices.

Standardization of produce, under the influence of supermarkets and big retailers, while fresh food, contrarily to industrial goods, is by essence diverse, a product of nature, difficult to standardize, is a major systemic cause of FLW in developed, and increasingly in middle income countries, as products that do not meet the standards can be rejected and discarded at various parts of the chain. Very often the consumer is not offered the choice of buying non-standard food, whether in size, colour, or even, degree of freshness.

With the expansion of supermarkets in developing countries (Reardon *et al.,* 2003; McCullough, Pingali and Stamoulis, 2008), there is a risk of even more FLW, given the difficulties of smallholders to comply with the various private standards imposed by supermarkets and big retailers (Berdegue *et al.,* 2005).In most civilizations, an abundance of food is a sign of wealth, feast, hospitality, good care of the family. As soon as income conditions and the relative value of food enables an abundance of food, there is a risk of waste. This tendency is especially developed in certain circumstances: holidays, "all-you-can-eat", feasts, etc.

In developed countries, especially for the rich and middle class, the increasingly low value of food relatively to other goods and services leads to, for households, less care in the management of their food basket.

In everyday life of urban lifestyles, often choices related to food consumption from frequency of buying, to cooking and eating are driven by time saving priorities (Soyeux, 2010), which could lead to food losses and waste. For example, when there is not enough time or possibility to shop daily for fresh food, the choice is often to have at home sufficient and diversified food needed for a longer period of time, leading to increased risk of FLW. At household level, the economic choice is, in such cases, rather to risk wasting than wanting. The transformation of food systems, driven by urbanization, income growth and globalization, introduces new challenges with risks of FLW. Trends towards growing consumption of more perishable and fresh products (Mena, Adenso-Diaz and Yurt, 2011), livestock products, fish, fruits and vegetables, including non-seasonal consumption of fresh seasonal foods, drive growing fluxes of these products, often on long distances. This requires efficient transport and logistics as well as good conservation techniques, combined with the implementation of good practices and food safety regulations along increasingly long food chains. This can be particularly challenging in countries confronted with a rapid change of food demand while rural areas still lack basic infrastructure. It should be noted that this is increasingly becoming a problem in developing countries where the proportion of population categorized as middle class is on the rise.

There is also a development of local food chains (Kneafsey *et al.,* 2013), especially for fresh and perishable products but little is known on its incidence on FLW. It could facilitate the commercialization of less standardized products and reduce FLW due to transport, as well as FLW at consumer level as time saved for the product to reach the consumer could translates into “food conservation time” gained for the consumer.

This Chapter has presented many causes of FLW along the food chain. It has identified three levels of causes and causal links between them. This can enable to make a context and situation specific diagnosis of FLW, in order to identify potential solutions (Chapter 3).

3 OPTIONS TO REDUCE FOOD LOSSES AND WASTE

In the previous chapter, reviewing causes of FLW along food chains from primary production to consumption, we have seen that there are many causes of FLW, that they are often linked and that they are also often very specific to the nature of different products and to local conditions. To clarify this apparent complexity, Chapter 2 distinguished three levels of causes: micro-, meso- and macro-levels. The importance of meso- and macro-causes stems from the fact that often causes of FLW of a physical, technical or behavioural nature are due to broader causes – economic, social and institutional.

A wide range of causes, organized in different levels, calls for a wide range of solutions, also organized in different levels. This chapter presents some solutions for reducing FLW along these three levels, starting by micro-level solutions (going along the food chain, from production to consumption), and describing the meso-level and macro-level solutions, as described in Table 2, which forms a grid of lecture of this chapter.

Table 2 Categories of solutions to reduce FLW by levels (micro, meso, macro)

	Levels		
Categories	**Micro (Section 3.1)**	**Meso (Section 3.2)**	**Macro (Section 3.3)**
Investments	Private investments in production, postharvest, businesses and food services. (3.1.2 and 3.1.3)	– Financial mechanisms – Collective private investments – Public investments (3.2.2, 3.2.4 and 3.2.3)	– Support to financial mechanisms – Infrastructure – Enabling environment – Proper incentives (3.3.1 and 3.3.2)
Good practices	Good practices in production and postharvest (3.1.1)	– Capacity building – Training (3.2.5 and 3.2.6)	– Support to capacity building – Multistakeholder initiatives (3.3.2 and 3.3.3)
Behavioural change	Behavioural change in businesses and consumers (3.1.4 and 3.1.5)	– Corporate social responsibility – Community and local engagement (3.2.6; 3.2.7; 3.2.8 and 3.2.9)	– Raising awareness – Multistakeholder initiatives (3.3.3)
Coordination inside food chains		– Food chain approach – Relationships with other actors in the food chain (3.2.1; 3.2.3; 3.2.7; 3.2.8 and 3.2.10)	– Enabling environment (contractual rules and incentives) – Policies (3.3.1 and 3.3.2)
Valorization of food and byproducts		– Food processing – Valorization of surplus foods and of by-products (3.2.4, 3.2.9 and 3.2.10)	– Support and incentives for implementation of a hierarchy of uses (3.3.2)
Coordination of policies and actions			– Policies – Multistakeholder initiatives (3.3.2 and 3.3.3)

The table describes how a solution (or a category of solution) at one specific level (on the left) can be supported or facilitated by higher level actions, at meso- and macro-level (on the right). Numbers in the cells of the table refer to the specific section of this chapter where relevant solutions are described, The first level of solutions (micro-level) is explored in Section 3.1. It is derived from the review of causes of FLW at each stage of food chains (Section 2.1), which leads to identification of potential solutions and actors to implement them, from farmers to consumers.

Section 3.2 explores solutions at meso-level. This level is particularly important for three reasons. First, solutions at micro-level often involve (or require) changes all along the food chain and, even when of a technical nature, generally require involvement of multiple supply chain actors and stakeholders (meso-level) or macro solutions, often economic and/or institutional. Second, solutions at micro-level can be – and often need to be – supported and enhanced by actions at a broader, meso-level. And finally, one key reason is the consideration of food chain logics, because in the absence of a concerted food-chain approach efforts at one step of the chain risk being annihilated at other step. Solutions at meso-level therefore, by definition, generally mobilize concerted and collective action (Section 3.2).

Solutions implemented at micro-level or at meso-level can be enabled, supported and enhanced by action at macro-level (Section 3.3). Very often macro-level solutions need a mobilization at national level to be implemented. This includes considering FLW in different sets of policies, and devising specific policies against FLW.

The whole will enable a better design of pathways for identifying and implementing strategies to reduce FLW (Chapter 4).

3.1 Single actor, technical or behaviour-driven solutions to reduce food losses and waste

At each stage of the food chain, specific causes of FLW (see Section 2.1 and Appendix 1) often call for individual technical or behavioural action by single actors, all along the food supply chain. As we have seen in Table 2, these cover mainly three categories of action: good practices, private investments and behavior change. In this section, we describe those by going along the food chain, from production to consumption. Post-harvest solutions range from improved practices in crop and animal production (Section 3.1.1) and investment in storage (Section 3.1.2) to adoption of technical innovations in transport, processing and packaging (Section 3.1.3). Technical and behaviour-driven solutions to reduce consumer waste include food service solutions in the hospitality sector (Section 3.1.4) and household-level solutions (Section 3.1.5).

3.1.1 Good practices in crop and animal production

When appropriately applied, good agricultural practices and good veterinary practices can protect food, at the primary stages of production, from damage or physical contamination by extraneous materials, pests, insects or vermin, and from biological contamination by mould, pathogenic bacteria or viruses – any of which can cause spoilage, crop damage and food-borne illness or even lead to chronic health consequences in humans. Increased human health risks may also result from consumption of meat products in such cases where animals were fed with contaminated feedstuffs.

The quality and safety of food intended for manufacturing or processing can be ensured by applying good manufacturing practices (GMPs) and good hygienic practices (GHPs) to food processing. When properly applied, these measures ensure quality and safety at all the processing steps from the receipt of the raw materials (primary products and other ingredients) to the shipping and marketing of the final products to the consumers. Implementation of GHPs entails the use of appropriate sanitary measures to prevent microbial contamination and assurance of optimum sanitary conditions for processing food products.

3.1.2 Storage and conservation solutions

A key intervention all along food chains is to improve storage conditions. For cereals and tubers, various solutions exist. There are a number of post-harvest technologies developed to protect stored grains from pests and other causes of losses, including, for example, organophosphate insecticides of low toxicity for mammalians, grain bags and metal silos (Tefera *et al.,* 2011). Availability and access to these solutions, including related cost considerations, is often a challenge for smallholder farmers (HLPE, 2013b). For instance, insecticide protection is recommended to protect stored grains, but is often unavailable or too expensive for smallholder farmers. Access to information on how to use these solutions is also key.

There are concerted efforts by researchers, donor agencies, governments, non-governmental organizations and other development partners to scale up successful affordable and adaptable storage technologies and solutions.

Among those is hermetic storage technology, where grains are loaded inside an airtight container, such as metal silos (see Box 6) or hermetic polythene bags, which stop oxygen and water movement between the inside and outside atmosphere: grain (and insect) respiration inside the hermetic container progressively consumes oxygen and produces carbon dioxide, at levels dependent on the number of insects, type and size of the container. When the oxygen level falls below 10 percent, insect activity stops, thus reducing pest damage (Baoua *et al.*, 2012). It also avoids the application of pesticides.

For preservation of quality of harvested perishable foods, the most important issue is temperature control. Refrigerated cold stores are the best option, but it is expensive in investments and running costs, and dependent on the availability of electricity sources, and therefore out of reach for the majority of smallholder farmers. Additionally, lack of connection to an electricity grid for most rural farmers complicates the introduction of electricity-powered cold rooms.

This calls for alternative, low-cost, electricity-independent options (see Box 7). Evaporative coolers offer, when water is available, one such alternative (especially in dry, low humidity air conditions) and there have been efforts to promote them in many developing countries. They can reduce temperature by 10–15 °C and maintain high humidity, which is beneficial to quality of horticultural produce for example.[19]

Box 6 Use of metal silos to reduce post-harvest losses in grains

Manufacture and use of the metal silo was first promoted in the 1980s by the Swiss Agency for Development and Cooperation in four Central American countries, namely, Honduras, Guatemala, Nicaragua and El Salvador. The promotion was conducted under the project POSTCOSECHA (Spanish term for post-harvest), in an approach directed to ensure that agricultural products can be stored for personal consumption or later sale. Adoption of the metal silos under the POSTCOSECHA project has had a great impact on the reduction of crop loss among the main staples (maize and beans), leading to enhanced food security. When properly used, crop loss can be reduced to almost zero (Tefera *et al.,* 2011).

Between 1997 and 2007, FAO distributed 45 000 metal silos to 16 countries: Afghanistan, Bolivia, Burkina Faso, Cambodia, Chad, Ecuador, Guinea, Iraq, Madagascar, Mali, Malawi, Mozambique, Namibia, Panama, Senegal and East Timor (Tefera *et al.,* 2011). These metal silos aided in storing about 38 000 tonnes of grain with an estimated value of USD8 million (FAO, 2008a).

The International Centre for Maize and Wheat Improvement (CIMMYT), in collaboration with the Kenya Agricultural Research Institute (KARI), the Catholic diocese of Embu and Homabay in Kenya and World Vision International in Malawi, initiated a pilot project on effective grain storage between 2008 and 2010 with the aim of reducing post-harvest losses and of promoting the technology in Kenya (Tefera *et al.*, 2011). Metal silos have been evaluated compared with farmers' polypropylene bags in Kenya. The metal silo proved very effective (<5 percent grain loss) over a 6-month storage period.

The main challenge to adoption of metal silos by smallholder farmers is the high initial cost, which ranges between USD40 and 350 depending on the storage capacity. However, given that they can last 10–20 years, metal silos more than pay for themselves through the accruing benefits, including food security and surplus grain savings.

The lessons learned from the pilot study in Kenya and Malawi include: (i) promotion of metal silos requires partnership among the government agencies, non-governmental organizations, manufacturers and farmers; (ii) technology uptake is highest where surplus production of grains is expected; (iii) effective communication and awareness creation is crucial in disseminating the technology; and (iv) a more comprehensive approach covering technology (more innovative post-harvest technologies), markets (private sector engagement in the market development of post-harvest technologies) and policy (policy environment for adoption of the technologies) is required.

Source: http://www.sdc-foodsecurity.ch; FAO (2008a) ; Tefera *et al.* (2011)

[19] http://ucce.ucdavis.edu/files/datastore/234-2143.pdf

Box 7 Improving fruits conservation in India

Pre-cooling of fruits and vegetables - The concept of pre-cooling of grapes was introduced in the 1980s primarily in the state of Maharashtra, which is the leading grape-growing state in India. This helped the farmers to export grapes to Europe, Gulf countries, etc. Later this technology was adopted for other fruits such as mango, pomegranate and orange.

Controlled atmosphere storage - With the onset of the twenty-first century, the need was realized to set up controlled atmosphere (CA) storage following the trends in Europe, the United States of America and other countries. A number of CA stores have already been established in the northern part of India at locations that have proximity to apple-growing regions. The capacities generally ranged between 1 000 and 12 000 tonnes. A few units of smaller capacities have also been established in the western and southern regions of the country.

Ripening chambers - There has been considerable interest in scientific ripening and storage of foods such as banana, mango, etc. in recent years and the units are being established in a number of places. A good development in this direction can be seen in southern India and in the states of Gujarat and Maharashtra.

Evaporative cool storage - An evaporative cool (EC) storage system maintains a 10–15 °C lower temperature compared with field temperature, and maintains around 90 percent of relative humidity. The shelf life of fruits and vegetables can be extended by 3 to 90 days depending on the produce. Since an EC storage system does not require energy input for maintenance, it is known as zero energy storage and is suitable for remote rural areas with extensive applications for storage of produce such as potato, yam, cassava, apple, orange, lime and tomato. Research institutes such as the Central Food Technological Research Institute (CFTRI) and the Indian Agricultural Research Institute (IARI) have developed a number of these rural-scale designs.

Source: http://agriexchange.apeda.gov.in; Yes Bank (2012).

There are different kinds of such evaporative coolers, of different technologies, designs and sizes, which can be adapted to diverse uses and scales. These range from pots (such as the *Janita* pot in India, *Zeer* pot in the Sudan), to charcoal coolers, brick and sand cool chambers, *Naya* cellar (in Nepal), among others. Available sizes range from small vessels holding a few kilograms to a walk-in cool room that can hold more than 4 tonnes. These simple, effective and cheaper alternatives can often be adapted to local conditions and small-scale production. However, they have not been widely adopted by smallholder farmers, partly because of lack of awareness and of proper support and incentives.

3.1.3 Technical solutions in transport, processing and packaging

Technical solutions in transport, processing and packaging need to be adapted to local situations, including the level of infrastructures, economic and human resources, as well as conditions along the rest of the food chain.

For instance, deployment of techniques and technologies grounded on cold might be unadapted in situations where there is no possibility to have a continuous cold chain, for example in situation where there is risk of lack of energy supply, unreliable transport, or lack of integrated cold-chain infrastructures down the food chain (markets etc.). See for instance the Section 3.2.3 on cold chains.

Development of solutions needs to be affordable and adapted to local conditions, including in terms of human resources and to the scale of operations in the food chain.

Often, quite simple and inexpensive solutions in transport, processing and packaging can significantly reduce the level of losses and waste in developing countries (UN Millennium Project, 2005; FAO 2011b).

In rural areas of developing countries, simple measures can reduce FLW in transport; for instance putting tarps over the truck to transport grain, vents in the trucks transporting fresh food and live animals to prevent heatstroke and, in both cases, transportation preferably in the evening hours to avoid the load deteriorating rapidly (Foscaches *et al.,* 2012).

Box 8 Promoting a two-stage grain drying technology in Southeast Asia

The Australian Centre for International Agricultural Research (ACIAR) set up R&D programmes in Viet Nam, Thailand, Malaysia and the Philippines to overcome losses and quality problems associated with drying grains in humid, tropical climates, with a focus on the rice industry. In Southeast Asia, especially for large rice exporters such as Viet Nam, a lack of drying technology is the main reason for grain loss and decrease in rice quality. The traditional drying techniques such as sun-drying were unlikely to reduce the moisture content to 14 percent, the safety level for long-term storage. In wet seasons, the moisture content could go above 30 percent, and it is difficult to find enough room and labour to dry the grains properly.

Concepts and impacts

The two-stage grain drying technology was developed, based on the use of a flash dryer or a fluidized-bed dryer in the first stage, for grain with high moisture content (>18 percent), followed by slower, in-store drying to reduce the grain moisture content to a safe storage level.

The ACIAR programme was successful in developing a drying technology that delivers a marked improvement in the proportion of rice meeting Grade 1 standards. The technology has been widely adopted in Thailand and there is growing interest for it in Viet Nam and China (Pearce and Davis, 2004). Economic analyses suggest that the two-stage drying technology, while more costly, has a positive impact on profit, largely from quality improvement (Chupungco, Dumayas and John, 2008).

Problems

There has been no adoption in the Philippines of the two-stage process as a whole or of either of its components. In recent years, the increase in energy prices has made the technology less attractive than when it was first developed. In many parts of Southeast Asia, rice-trading sectors are still characterized by small traders turning over small volumes of rice within a short amount of time. The two-stage technology requires significant initial investment in drying facilities (often including shed space), which means an increasing return to scale. Large bulks of rice handling are required, which asks for structural change in the rice industry with small-volume trading.

Source: Chupungco, Dumayas and John (2008); Pearce and Davis (2004).

Box 9 Improving drying technology for omena fish on lake Victoria

Fresh omena fish cannot last more than two days before it is completely deteriorated for human consumption. It is therefore generally dried. Drying omena on the beach is usually done on fishing nets that are hired from the fishermen at a fee. The women use brooms to turn the omena. The hygiene on the landing beaches is low. Animals can wander freely on the beach where they eat the dropped fish. Bigger omena takes longer to dry and, during the rainy seasons, traders may suffer up to 80 percent economic losses especially if there is insufficient sunlight to dry the fish for more than two days. Omena fish is transported to the market in airtight sacks and transported on public transport. The sacks do not allow air circulation and may cause deterioration, especially if the fish was not well dried.

Recently, a non-governmental organization that is helping communities to export omena came up with a new design for drying. This consists of raised racks within a fenced area. The racks are covered with polythene covers to protect the fish from wind, dust, rain and other elements. The polythene helps to trap heat and therefore the fish will dry faster on cloudy days. In order to benefit from the intervention, traders must commit themselves to certain hygienic standards for handling the fish and must also organize themselves in groups. This technology is adapted to local conditions and is cost effective.

Source: FAO (2014c).

As seen in Chapter 2, insufficient or inadequate packaging can be a factor of food losses and waste. Losses at almost every stage of the food chain may be reduced by using appropriate packaging, as a key element of a set of technologies and processes to reduce losses (Olsmats and Wallteg, 2009).

Improved packaging and the packaging industry has a key role to play in addressing food losses but also in ensuring food safety as well as facilitating storage and transport of food, which are important for trade. Packaging solutions should also take into account the need to reduce waste in general and be adapted to local producers/packagers as well as to consumers' needs (FAO, 2011b).

Box 10 Plastic Food Containers Bank in Brazil

In this system, the producer – or even the intermediate – rents boxes of diverse sizes adapted to the product to be transported, which are taken to the rural area already cleaned and sanitized. At product delivery in the Food Terminal, the producer receives the same amount of empty boxes for holding the next transport. At the same time, the boxes that are emptied are subjected to cleaning and sanitizing. According to the boxes' manufacturers, the loss can be reduced by 30 percent with this system, but so far there is no evidence to establish the exact percentage of loss reduction. The difficulties in measuring this gain arise from the fact that the system was not well received by producers and intermediaries. This is because the old system, based on standard wood boxes, was cheaper for the farmer and allowed the intermediary to still make a profit by trading boxes. In the new system, in addition to revenue losses from the sale of boxes, the producer or the intermediary would have to pay a fee to the Food Terminal for the use of plastic boxes. Moreover, the simplification of the activities of loading and transhipment threaten a large number of workers whose livelihood depends on these activities.

Source: Belik (2001)

The development of modern packaging can result in food savings: options range from "easy to empty" packaging, to portion sized packaging, breathable polymer films, aseptic technology, modified atmosphere packaging, hermetic seals, re-sealable packaging, or smart packaging. Smart or intelligent packaging tracks through sensors some physical variables inside or outside the package, which either influence the quality of a product or are a sign of its quality (ripeness, freshness). It can thus monitor the safety and quality condition of a food product and provide early warning to the consumer or food manufacturer, better inform decisions and avoid losses of products that are still of good quality. For instance, it can monitor temperature or presence of oxygen in the package. Another promising technique is to measure the presence of an elevated CO_2 level, which can be the prime indicator of food spoilage in packed foods. Its maintenance at optimal levels is also essential to avoid spoilage in foods packed under modified-atmosphere packaging (MAP) conditions. Hence, a CO_2 sensor incorporated into the food package can efficiently monitor product quality until it reaches the consumer (Pradeep, Junho and Sanghoon, 2012). Packaging that carries information on how food should be best conserved and stored also leads to FLW reduction.

Many technical solutions in transport, processing or packaging, encounter constraints to their acceptance or implementation, which often requires enabling changes at meso-level in the supply chain, or sometimes even at macro-level, as existing interests and dominant practices could be barriers to adoption of the solution. An interesting case here is the Brazilian experimental system of the Plastic Food Containers Bank run by the Food Logistic Terminals in some cities (Box 10). This case shows some of the challenges to implementation of solutions in the medium and long term, and the increasing need to rely on institutional[20] efforts involving all actors in the chain, including private actors.

3.1.4 Solutions for the hospitality sector

Food services in the hospitality sector (hotels, restaurants, canteens, catering, etc.) can play a double role in a FLW reduction strategy, by reducing their own losses and waste and also as key places to raise awareness of consumers, to experiment and to understand consumer behaviour. Liu (2014) found that in China most of consumer food waste is in the catering and restaurant sector.To reduce FLW in food services and catering businesses, a first step is to measure and track the amount, type of and the reason for FLW. This can serve as a basis to establish a waste reduction strategy in individual businesses. For instance a guide to reduce FLW in the hospitality sector has been developed in Catalunya (Spain) detailing practical measures, from stock management to menu design (Alícia/UAB, 2012).

The US Environmental Protection Agency has developed a Food Waste Assessment Tool,[21] in the public domain, which consists of a series of spreadsheets that compute costs and benefits of waste reduction options, such as source reduction, reuse of leftovers, use as animal feed, composting, etc. It also computes associated savings in greenhouse gas emissions.

[20] Institutions are understood here as institutional arrangements or governance, which is the space in which the actors interact and build their strategies. In this sense, we can say that the markets as institutions are not given, but *constructed* by social actors.

[21] http://www.epa.gov/foodrecovery/tools/index.htm

Box 11 An experience of tray-less catering in the United States of America

Researchers quantified the impact on plate waste of switching from a tray to a tray-less delivery system in a university dining hall serving roughly 1 000 meals a day. Liquid and solid plate waste were measured for one week with a tray system and again after introduction of a new tray-less system. Food service staff were invited to participate in a focus group about the impact of the measure on their working conditions. A significant 18 percent solid waste decrease per client was observed in the tray-less system. A less significant 7 percent liquid waste reduction was observed. Most of the food service staff preferred the tray-less system as long as it did reduce waste, but felt that it increased breakage of dishware and increased the need to wipe down tables. This study demonstrates that tray-less dining can reduce waste in plates, and that clients and staff can both be supportive of the change.

Source: Thiagarajah and Getty (2012)

More sophisticated systems can monitor all operations in the production of meals, photographing the leftovers and weighing the quantities discarded. In the modern systems, it is possible to calculate the cash values that were being lost by identifying the type of food being discarded and its weight, using a scale attached to the computer.

There has been empirical evidence on the effectiveness of food waste prevention and mitigation strategies focusing on prevention/behavioural change (see Box 11). Examples are most commonly found in the canteens and catering sector. Quantified case studies include Getlinger *et al.* (1996) on elementary schools; Li *et al.* (2003) on in-flight catering; McCaffree (2009), Thiagarajah and Getty (2013) and Cohen *et al.* (2013) on comparisons of food service systems; and Whitehair (2013) on the influence of written messages on catering customers' behaviour.

The effectiveness of a single measure of reduction of food waste in the hospitality sector is always difficult to assess, as FLW is influenced by many interlinked factors. Evidence shows that the best option is to use a combination of business and consumer-oriented strategies. In Brazil and Portugal, restaurants "a kilo", where consumers only pay for what they take, as opposed to "all you can eat" formulas, are a good example of bringing closer, for the consumer, the economic value of food and the cost of waste (Generalitat de Catalunya, 2011). In a "pay by weight" restaurant, there is an economic incentive for consumers "not to waste", and to adjust the size of the meal to their real needs, not more, as what gets wasted could have been saved in terms of meal cost, making "waste reduction" behaviour a means to optimize meal costs. In Portugal many restaurants offer, along with the classical menu, a menu with smaller portions at a smaller price.

3.1.5 Solutions for households

Consumer waste is often presented, as in some of the approaches mentioned in Chapter 1, as the result of carelessness, and as easily avoidable. Detailed studies mentioned above in chapter 2 show a much more complex picture. Most of the time, consumers are reluctant to discard food, which is why to do so they wait until the expiry date, even when they know that they are not going to use the remaining food (Evans, 2011a). They keep food remaining from a meal in the fridge, or the freezer, before discarding it (HISPACOOP, 2012) even knowing that they will probably not use it.

Recent surveys in Spain (MAGRAMA, 2013) and Portugal (Baptista *et al.,* 2012) have asked consumers if the economic crisis has reduced their food waste. In Spain 41 percent responded that they have done so and 13.7 percent that they reuse products, such as oil.

According to Baptista *et al.* (2012), which conducted open interviews, these changes seem to be driven more by ethical considerations than by strict economic reasons. Researchers have mentioned (Evans, 2011a) that the sole fact that there was research on FLW tends to reduce effective FLW in the researched households.

In other words, consumers do not want to waste, they often feel guilty when doing so, and also most of the time are not aware of the extent of their waste (see above). It first shows that, to a great extent, FLW at household level are caused by behaviours that are often not directly identified as ultimately causing FLW, and/or that are not easily modified, because they are part of much more complex lifestyles. On the other hand, and precisely because consumers do not want to waste, raising wareness on the extent of their own waste can be a very effective way to motivate change.

Several studies (Quested *et al.*, 2013) have detailed measures that consumers could implement to reduce their own food waste. These include:

- Better planning of purchases to avoid buying more than is needed.
- Avoid impulsive or advance purchasing of food that is not required immediately.
- Better understanding of the distinction between “best before” and “use by” dates (see Section 2.2.4).
- Better storage practices and stock management in the home.
- Better evaluation of the portions that need to be prepared.
- Better food preparation techniques, to avoid food being not eaten and food quality losses and waste (FQLW and nutritional content decrease) due to the preparation method.
- Making full use of fruits and vegetables to extract all the nutritional benefits.
- Better knowledge on how to use the leftovers on other recipes instead of discarding.

3.2 Concerted and collective solutions to reduce FLW

Technical or behaviour-driven single actor solutions to reduce FLW often need, as we have seen, to overcome a specific constraint in order to be implemented. These constraints are often found at meso-level, as we have seen in Chapter 2, and they are *de facto* meso-causes of FLW.

As Table 2 shows, meso-level solutions can support investments, good practices and behavior change, at each step of the chain. Two other important categories of meso-level solutions are linked to improved coordination inside food chains and to the valorization of food and by-products.

Solutions to overcome these meso-constraints and fight these meso-causes are depicted in this section, and grouped in ten main categories:

1. Adopt a food chain approach to FLW reduction actions (3.2.1).
2. Invest in infrastructures (3.2.2).
3. Invest in adapted cold chain developments (3.2.3).
4. Develop food processing (3.2.4).
5. Ensure proper capacity building, education, training and extension services (3.2.5).
6. Unleash the crucial role of women to reduce FLW (3.2.6).
7. Allow a role for corporate social responsibility (3.2.7).
8. Promote consumer behaviour change (3.2.8).
9. Give value to surplus “saved” food (3.2.9).
10. Valorize by-products, side streams and non-used food (3.2.10).

3.2.1 Adopt a food chain approach to FLW reduction actions

Food losses and waste progressively “cumulate” along the chain from production to consumption. To reduce overall FLW for a produce, one needs to consider reductions all along the chain, adopting a food chain approach, for three key reasons.

The first reason is that there are many causes of FLW that are linked to a lack of coordination in the food chain (see Chapter 2).

A second reason, as also shown in Chapter 2, is that causes of losses can occur at a different stage than where losses effectively appear. Behavioural or economic choices that seem rational at one stage of the chain may lead to FLW when the rest of the food chain is considered.

Third, a key reason is that efforts at one step of the chain, for example to preserve the quality of the produce early in the chain, can always be “lost” in successive stages. In Kenya, for instance, the banana supply chain has been identified as a priority. Many initiatives to build capacity at farm level have considerably improved post-harvest handling and the quality of produce leaving the farm. But such good practices at early stages of the chain are not followed by traders who handle the produce in large quantities and for long periods, take the highest risks of bulking, transporting, ripening and selling in urban areas. Adopting a food chain perspective shows how important the need is to focus capacity building on these traders (FAO, 2014c).

Box 12 Food chain approaches to minimize losses in the dairy sector in Kenya

Recent evolutions in the Kenyan dairy industry (FAO, 2014b) provide good examples of how the various actors and dimensions need to interact along a supply chain to ensure quality. There is increasing demand for dairy products in Kenya, leading buyers/processors to support backward linkages to secure milk supplies from farmers and farmers groups. This also drives an increased formalization of the small-scale sector.

In 2004 a package of measures was designed to formalize the participation of small milk traders. Rules were published to allow licensing by the Kenya Dairy Board (KDB) of small-scale milk traders. Among the requirements to get a bar licence is to have a system for milk cooling. Modules were developed for training (milk handling, processing and marketing), with a good manufacturing practice (GMP) targeting small-scale milk traders operating milk collection centres and processing plants. A code of hygienic practice for the dairy industry was also developed to educate players along the value chain on the requirements of hygienic milk handling practices. The Dairy Traders Association (DTA) of Kenya was officially launched in September 2009. Its aims and activities included self-regulation based on training and certification. Around 4 000 small-scale milk vendors, offering employment to over 10 000 people, have since been trained, certified and licensed by the KDB through the association.

Several projects have been conducted, with the support of the World Bank (Eastern Africa Agricultural Productivity Project), of the Bill and Melinda Gates Fundation (East African Dairy Development Programme), of USAID (Kenya Dairy Sector Competitiveness Programme), and of IFAD (Smallholder Dairy Commercialization Programme), to develop the sector. They generally combine measures to support the organization of producers, bulking milk to facilitate marketing and benefit from economies of scale, and include various measures to improve milk quality and reduce milk rejections.

The quality of the milk and risks of rejection are closely dependent on the details of the organization of the collection. For instance, in the Mathira Dairy Farmers' Society, milking is done at 04.30 hours, collection starts at 05.00, with each vehicle having a daily route of 3 to 4 hours. For each vehicle there is a controller who weighs the milk and tests its quality with a lactometer and occasionally an alcohol test. Evening milk is tested and bulked separately.

Source: FAO (2014b)

For many products where risks of microbial contamination are important, ensuring quality and food safety and minimizing FLW require actions all along the chain. Milk is a good example (see Box 12) as it is a very perishable product, subject to microbial contamination, and its quality is thus very susceptible to all operations along the supply chain. In addition, low quality milk can quickly contaminate a whole bulk and thus lead to its total rejection.

3.2.2 Invest in infrastructure

As mentioned above, reducing FLW often involves improving infrastructure, particularly transport, energy and market facilities. This requires government action, often with the involvement of local authorities and also of the private sector. For instance, the Government of the United Republic of Tanzania project (MIVARF) is investing in market infrastructure, roads, value addition centres (packing houses and food processing) and rural finance.

Agro-logistics concerns all activities in the supply chain to match product supply from the farm with market demand for those products (van der Vorst and Snels, 2014). It aims at getting the right product, at the right place, at the right time, according to the right specifications (including quality and sustainability requirements), at the lowest cost. Actors in these types of chains understand that original good quality products might be subject to quality decay because of an inconsiderate action of another actor. It is therefore a way for coordinated action to reduce FLW along the supply chain.

Building proper infrastructure, notably storage infrastructure, is another way to fight FLW at collective level.

Collective storage, which can include the mutualization of risks of post-harvest losses, is also a solution. Its effectiveness depends on the local institutional context, such as existence of local institutions, cooperatives or producers' organizations. In China, over 50 percent of grain is stored by farm households, 25 percent by commercial enterprises and 25 percent by local and central governments with high losses in farm storage and low in public ones, close to the developed countries' level (Liu, 2014).

Box 13 Warrant experiment in China: a financial innovation to reduce post-harvest loss

A survey by the State Grain Bureau of China in 2009 showed that the average loss of grains stored by rural households reached more than 8 percent. The loss was mainly due to the poor storage infrastructure. Among various efforts to reduce post-harvest loss, one noteworthy effort is the experiment of warrants (also called “food bank” in China). It is a quasi-financial arrangement that allows farmers to “save” grains in a grain-trading company and farmers have the ownership of the grain while the company has the use right. Then the company earns profits by trading grains and part of that profit is returned to farmers as “interest”.

An experiment of warrant was initiated in the 1980s in Guangrao County in Shandong Province. The Guangrao County Court started a business called *liangdaiyihuan* in which the Court would preserve, process and exchange grains for the farmers. In 2007, the first official “food bank” was set up in Taicang County in Jiangsu Province. This system brings drying, processing and storage facilities for farming households, reducing losses.

The system has expanded in recent years. Major grain production provinces such as Heilongjiang, Henan, Sichuan and Hubei have all started the experiments. In 2011, Taicang County in Jiangsu Province estimated that warrants led to saving 3 900 tonnes of grains for the county every year.

However, such an expansion is facing challenges. For example, in Changle County in Shandong, more than 90 percent of warrants suffered a loss due to the large fluctuation in grain prices. The National Development and Reform Commission has attempted to advocate for the initiative as a new arrangement to preserve grains and increase flexibility in the agricultural food market. However, due to the experimental nature of the system, many legal and financial issues remain and are not clarified.

Source: http://www.ebdoing.com/Html/News26.htm; Liu and He (2012).

Collective storage can be coupled with “warrant” systems, which also brings the advantage of providing credit to the farmer.

In China, in the past three decades, efforts to reduce food losses have historically been carried out mainly through government food storage. In recent years, an experiment was launched for farmers’ grain storage with a food bank (see Box 13) and storage infrastructure. This subsidy programme was piloted in three major grain production provinces in 2007 and is planned to expand to 24 provinces in 2016. The programme is targeted to cover eight million farmers and an estimated 5.5 million tonnes of farmers’ grain storage. It is accompanied by the Development Plan for the Vegetables Industry by the National Development and Reform Commission and Ministry of Agriculture, which plans to reduce post-harvest losses of vegetables significantly in 2011–2020.

In Kenya, several initiatives are promoting and supporting collective storage of maize, including Purchase for Progress (P4P) a programme of the World Food Programme.

3.2.3 Invest in adapted cold chain developments

Often the efficiency of FLW reduction depends on broader interventions involving private actors all along the food chain and/or public actors. This is particularly the case when the main solutions reside in improvement of logistics. Cold chain management in perishable foods supply chains offers a very good example of potential solutions and what is needed to implement them.

A cold chain refers to an uninterrupted series of activities that maintain a given temperature range from the production point to the consumer. Effective cold chain management starts with pre-cooling, cold storage, refrigerated transport and refrigerated display during marketing. The International Institute of Refrigeration (IIR) calculated that 23 percent of perishable foods are lost in developing countries due to the lack of use of refrigeration (IIR, 2009).

Strategies to invest in cold chain development could also start with interventions by governments and development partners to improve the cold chain infrastructure in developing countries, as the example of India shows (see Box 14).

Such interventions can target for instance the introduction of collective cold-storage facilities. In Kenya, the Japan International Cooperation Agency (JICA), working with the Horticultural Crops Development Authority (HCDA), introduced conventional cold rooms in strategic locations to cater to smallholder farmers almost ten years ago.

Box 14 Cold chain intervention in India

The Government of India, on the basis of various industry recommendations, established an autonomous body, the National Centre for Cold Chain Development (NCCD), in July 2012, to promote and develop integrated cold chains in India for perishable agriculture and horticulture produce. The main objectives of the Centre are to recommend standards and protocols for cold chain infrastructure, suggest guidelines for human resource development and to recommend an appropriate policy framework for development of the cold chain. NCCD is intended to serve as the nodal agency for India's cold chain development, the centrepiece for all future support interventions in this sector. As the nodal body, the NCCD is to recommend policy interventions, take on capacity building and skill-development initiatives, recommend standards and certifications and basically act as guide and mentor to the cold chain industry. In addition, the Government also constituted a Committee on Supply Chain and Logistics (focusing on post-harvest marketing).

The National Horticultural Board, an autonomous society under the Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, has taken a big step in creating technical standards for cold chain projects. Government agencies such as the National Horticultural Board, the National Horticultural Mission and the Ministry of Food Processing Industries offer financial incentives for the new projects as well as for expansion of existing units. However, these projects have to be, essentially, based on modern and efficient technology in tune with the technical standards.

Source: http://www.nccd.gov.in

These facilities have often mainly benefited intermediaries and brokers rather than the intended target users (smallholder farmers). Another initiative seeking to support smallholder farmers in groups is the promotion of devices allowing the use of standard air conditioning equipment to reach colder temperature by overriding their frost control mechanism. This technology has been widely adopted in India, the United States of America and Bangladesh and is on a pilot scale in Kenya, the United Republic of Tanzania, Rwanda and Uganda.

In Tunisia the development of the cold chain is part of the food security strategy, along with improving controls and harmonization of food safety and quality towards international standards. It is supported by a national plan for cold, with incentives to investments. This strategy has enabled to increase by 65 percent in 10 years the cold storage capacity, which is completed by 3000 refrigerated vehicles and 1500 isotherm vehicles. 70 percent of it is dedicated to fruits and vegetables, mainly for export. 87 percent of this storage capacity is managed by the private sector. Tunisia is now also developing solar cooling. However this dynamic development of cold chains encounters some challenges: under - utilization of some of the capacity because of the seasonality of the production, uneven territorial distribution of the capacity and lack of trained technicians, with an important differentiation between export and national oriented structures (FAO & IIF, 2014).

3.2.4 Develop food processing

Food processing can be defined as the transformation of raw ingredients and intermediates into products intended for human consumption, with the purpose of improving digestibility, bio-availability of nutrients and energy, taste, appearance, safety, storability and distribution. It is an effective way to stabilize and conserve perishable products. Preservation processes, such as canning, pasteurization and sterilization, and packaging technologies, contribute to increasing the shelf-life of products, thereby reducing losses and waste in the chain (Langelaan *et al.*, 2013).

In some developing countries, there have been efforts to promote fruit and vegetable processing into dried/dehydrated products, juices, concentrates, jams and purees as a measure to reduce post-harvest losses, especially during the high season or a bumper harvest (See also Box 18 in Section 3.2.5).

Developing food processing necessitates developing appropriate processing technologies and infrastructure, in a concerted food chain approach (as for example in atmosphere packaging, see Box 15). It needs improved access to and knowledge about various technologies along food chains (FAO, 2013d).

Box 15 Modified atmosphere packaging in the fresh meat supply chain

In the past decade, a major transition evolved in the Dutch fresh meat industry with ramifications for the entire meat business. In 1995, more than 95 percent of all fresh meat products for consumers were either sold loose or packed on a white styrofoam tray with stretch wrap. Almost a decade later, about half of the meat industry has adopted the modified atmosphere packaging (MAP) technology. Strikingly, the first trials with this technology had already been conducted in the Netherlands in 1964, but it took four decades for the technology to conquer the Dutch meat industry. The technique diminished the product losses in fresh meat sales.

Source: Thoden van Velzen and Linnemann (2007).

Investment in food processing infrastructure, including packaging, can further be seen as a huge opportunity to contribute to improved situations of food security, especially in sustainable ways to fulfil the growing demands of metropolitan areas.

Strategies for development of a food processing sector could be based on insight into the market demands and forecasts, bottlenecks that need to be overcome, and an analysis of the sector characteristics. Combining these sector and market insights with supply chain structure information would identify market potential, this being an important driver for the development of business cases and getting the involvement of investment, technology suppliers, institutions and entrepreneurs. An example of such an approach is the study on food processing and business opportunities in Ethiopia to identify possible interventions that might increase the processing and preservation of food at all levels, by looking at the current market and its bottlenecks (Soethoudt *et al*., 2013). This would indicate that structural investments in food processing infrastructure in developing countries can only succeed if, besides the technological challenges, the crucial appropriate links and actions at meso- and macro-level are in place.

3.2.5 Ensure proper capacity building, education, training and extension services

Capacity development in the form of education, training and extension services for farmers and all actors along the food chain is a key tool for reducing food losses and waste. There is a need for capacity development at all stages of the food chain. It includes improvement of production practices through information sharing at community level and farmer field schools. Programmes should be designed and implemented to develop capacity in food chain improvement, value addition, packaging, HACCP systems, quality and safety, good practices, sorting and grading, transportation, traceability and storage.

These topics could be integrated in dedicated academic programmes on post-harvest issues (FAO, 2013d). For instance, the AVRDC[22] Postharvest Training and Services Center (PTSC) in Tanzania offers a locally suitable menu of postharvest technologies and marketing options for farmers, traders, processors and marketers.

A crucial element is to increase capacity in specialized human resources for operating, maintaining and repairing machinery as well as for drivers and workers on the logistics chain for appropriate product handling. Such actions could build upon experiences and good practices of other sectors and countries.

Capacity building can take diverse forms (see Box 16). There is a need to develop formal and informal institutions which reach all actors, particularly small-scale. This also involves training of trainers (see Box 17).

Access to knowledge has been identified as a key area (FAO, 2013d), where networks could stimulate the sharing of knowledge competencies, innovations and good practices (see Box 18).

[22] www.avrdc.org

Box 16 Capacity building initiatives for food loss prevention in Latin America

The Inter-American Institute for Cooperation on Agriculture (IICA), by means of survey, identified high level of discards in important products for domestic consumption, as high as 40 percent in potatoes in the Andean region and 35 percent in vegetables in Haiti. There are also high losses for export crops such as bananas in Ecuador or pumpkin in the Caribbean countries. Lack of cold chain devices, inappropriate handling and packaging, and lack of market and climate information for producers making them take wrong decisions about what, where and when to plant were identified as main causes. Investments in training, equipment and market information were identified as solutions. The IICA initiative brings partnership agreements between American universities and local organizations and the possibility of bringing international donations for these projects (IICA, 2013).

On the other hand, from the same diagnosis but following a bottom up approach, the root organizations in Latin America are boosting the exchange of information among producers. Movements such as the *Campesino a Campesino* (CaC) or Farmer-to-Farmer Programme promote the technical exchanges between producers and farmer's visits and training. The CaC uses the ancestral knowledge of the farmers producing immediate results in the application of simple technologies (IFAD, 2010). Likewise and with the same philosophy, the peasants' knowledge transmission is supported and disseminated by international organizations such as the Food First Institute. Other important organizations such as *La Via Campesina* and Action Aid are supporting similar initiatives.

Source: IICA (2013), IFAD (2010)

Box 17 Training of trainers in post-harvest handling of perishables

The Postharvest Education Foundation (PEF) is a private sector initiative and a non-profit organization training young people in developing countries on various aspects of post-harvest handling of perishable commodities including fruits, vegetables and root crops. It trains groups of diverse stakeholders in various aspects of post-harvest handling. Some of the topics addressed include when to harvest, how to keep foods safe to eat, how to clean, pack and store fresh foods, how to process perishable foods into products with longer shelf life. Through the training, trainees are empowered to tackle the post-harvest issues in their own countries, by working directly with farmers, food traders and marketers, and providing information, demonstrations and education in their own local languages. Since 2011, the PEF has provided long-term, intensive training, covering trainees from 17 different countries (referred to as master trainers). Those have in turn organized training in their respective countries to pass on the acquired knowledge and skills. The training approach includes a written training manual (Kitinoja and Kader, 2003) and fieldwork assignments to make sure the trainees gain practical, hands-on experience.

Source: www.postharvest.org

Box 18 Sharing knowledge and competencies on post-harvest losses: the project of a network of excellence

The initiative of a Network of Excellence on postharvest food losses (NoE) is a Dutch-led public-private cooperation project aiming to develop and apply knowledge on post-harvest issues for perishable food products in emerging and developing countries, in Africa, Asia and Latin America. The overall objective is to reduce losses in the food supply chain and improve overall performance in these chains. Expected missions of the NoE are: improving access to knowledge on various post-harvest issues and supply chain efficiency for chain actors and stakeholders in the targeted countries; capitalizing on public and private organizational experiences in these countries; joint consideration on post-harvest development and food loss reduction; a demand-driven approach to initiate actions upon articulated post-harvest questions from chain actors; and linking with networks active in developing markets, including knowledge institutes, extension service providers, chain actors and NGOs. Building a network of capacities with regional applied research institutions and sharing of frameworks, toolboxes, methodologies and best practices is an important activity.

Source: van Gogh *et al.* (2013).

3.2.6 Unleash the crucial role of women to reduce FLW

In most rural communities, women constitute two-thirds of the agricultural labour force and up to 80 percent of the total food production work force (see e.g. Humera *et al.*, 2009 for case studies in Pakistan).

Women play a key role in post-harvest handling, mainly drying, threshing, dehusking, shelling, grading, cleaning, initial processing and storage of food grains (e.g. Sidhu, 2007). These are drudgery-prone tasks and it is recorded that high losses occur during these post-harvest activities.

Apart from the grain crops, women in many developing countries are responsible for growing and processing highly perishable crops such as fruits, vegetables and tubers. They are also the ones charged with preservation and storage of foods such as milk, meat and fish.

Despite the key role they play from production to food processing, women in developing countries experience barriers in the post-harvest handling practices. Most of them lack knowledge of and access to good processing practices and efficient processing tools. Additionally, they are often excluded from training opportunities because most producer organizations, through which such capacity-building efforts are conducted, are dominated by men. As a result, women farmers end up with inferior processed products that cannot meet market standards and are therefore discarded or sold to alternative markets for lower prices.

There are initiatives from government and development partners in developing countries to improve the livelihoods of women farmers through value addition and marketing of perishables food crops such as fruits and vegetables. These initiatives have two-pronged benefits – economic empowerment of rural women and reduction of post-harvest losses in the perishable commodities.

In Kenya, initiatives by GIZ and the Ministry of Agriculture have seen farmers (especially women) trained in solar drying of fruits and vegetables, as well as in making products such as juices, pulp, jams and chutneys (see Box 19).

Box 19 In Kenya Ukambani women reaping profits by processing fruits

Mango is one of the major fruits produced in the Eastern Province of Kenya. The mango season in this province is from December to March. During this peak season, there is a glut and limited market for the fruits leading to high losses. The farmers sell four mangoes at 10 shillings (USD0.1) to traders who transport them to urban markets and sell at 20 shillings (USD0.25) a piece. The Arid Lands Resource Management Project (ALRMP), in collaboration with the European Union, has developed an initiative to add value to products seen to have low value in the area. The initiative was meant to empower women and the community to maximize profits and reduce the losses by processing the fruits. The fruit growers have realized that mangoes and paw paws, which used to rot in farms, would not go to waste again.

A local non-governmental organization, Kithethesyo Women Self Help Group, in Migwani division benefitted from the initiative and ALRMP provided training and advanced 315 000 shillings (USD4 200) to the 40 members women group to buy a fruit processor.

The initiative was a turning point for the women's group. "*The machine can squeeze 100 litres of juice from mangoes and paw paw jam in less than an hour*", said the group chairlady, Phoebe Kasee. She explained that the juice was then blended with preservatives, hot water and citric acid to produce a rich and tantalizing natural juice that can compete with other products in the market. "*The shelf-life of mango juice is 18 months while that of the paw paw jam is 36 months*", said Kasee. She acknowledged that the members have greatly improved their income as mango juice goes at 80 shillings (USD1) per litre while the same quantity of pawpaw jam sells at between 120 and 150 shillings (USD1–2).

"*I personally have been able to build a decent house and educate my children from the juice products*", said Kasee, asserting that in the past it was difficult for one to get 2 000 shillings (about USD30) from their harvest of mango and pawpaw.

Source: www.coastweek.com. Publication date 5/3/2010.

3.2.7 Give a role to corporate social responsibility

The increasing inclusion in annual corporate businesses reports of a section detailing the environmental and social impacts of their activities could lead to more sustainable food systems and less FLW.

Corporate social responsibility (CSR) approaches can guide investment decisions by stakeholders and stock markets, favouring the market value of companies classified as "green". Businesses positioned as "chain coordinator" could, in adopting FLW targets, play a particular role in FLW reduction, potentially extrapolating national boundaries.

With respect to FLW reduction, businesses can commit to further transparence (see Box 20) and report (i) on monitoring on food losses and waste in their activities; (ii) on reducing food losses and waste in their activities; and (iii) support activities that lead to reduction of FLW elsewhere, with their suppliers, at consumer level or elsewhere.

In Argentina, the CANALE group is supporting a programme to promote sustainable food consumption through training programmes in more than 90 schools. In three years, 2 000 children and 100 teachers have been trained. The firm MONDELEZ, with the Argentinian Red Cross, conducts a programme for redistribution of fresh fruits and vegetables fit for consumption but with cosmetic imperfections that make them unmarketable. From 2009 to 2012 the programme has distributed over 3.6 million tonnes of fresh fruits and vegetables to more than 230 000 people.

Box 20 Transparency and actions of retailers on food losses and waste reduction

In October 2013, Tesco, a main retailer in the United Kingdom, announced that it would publish figures about food losses and waste within its own operations and in the total supply chain. The transparency about figures is considered to be an important step forward. Other United Kingdom retailers have been under pressure to act after Tesco admitted it generated 28 500 tonnes of food losses and waste at its stores and distribution centres in the first six months of 2012 alone. In response, the retail industry organization, the British Retail Consortium (BRC), announced in January 2014 that the big four supermarkets, Tesco, Asda, Sainsbury’s and Morrisons, as well as Marks & Spencer, Waitrose and the Co-op, will release regular updates on the amount of food lost or wasted in their stores. The first data will be published early in 2015.

In the Netherlands, since 2011 the largest retailer, Ahold, publishes data on food lost or waste in its Corporate Social Responsibility report. In 2012, the volume of food loss and waste was between 1 and 2 percent of total food sales, with fresh food loss and waste between 2 and 3 percent and dry food loss and waste between 0 and 1 percent.

Source: Tesco (2014).

3.2.8 Promote consumer behaviour change

Consumer research studies have shown that consumers are largely unaware of the levels of food waste generated. Raising awareness on the amount of household FLW and its cost is a first step. Consumer behaviour is identified as being complex, inter-linked and self-reinforcing where self-awareness can be a powerful trigger to alter behavioural outcomes (Bond *et al.,* 2013).

There are two main ways of reducing the amount of FLW at home, by influencing people's action or by making changes in the food that is sold, for instance changing packaging or extending shelf life (Quested *et al.*, 2013).

Reducing developed-country consumer food waste is particularly challenging, as it is so closely linked to individual behaviour and cultural attitudes towards food. Waste may be reduced by alerting consumers to the scale of the issue as well as to domestic strategies for reducing food discards. Advocacy, education and possibly legislation may also reduce discards and waste in the food service and retail sectors. Nudging is considered as a potential tool to influence consumer choice in an effective way in complex behavioural challenges and literally means giving someone a push (a nudge) in the right direction. Nudges stimulate a specific product or behaviour choice in a non-coercive way by making changes to the surroundings in which choices are made. Currently, evidence gaps exist around how to nurture a social environment where consumers are nudged towards sustainable and healthy food choice (Bond *et al.*, 2013). Some current FLW reduction initiatives (see Section 3.3.3) broadly adopt these approaches, such as the Love Food Hate Waste campaign in West London, or the Food Battle initiative in the Netherlands.

The importance of reducing food waste, the factors affecting consumer food waste worldwide, and related actor-level solutions (see Section 3.1.5) will often require promotion among consumers, communication and awareness raising. Retailers, because of their proximity to consumers, can also play an important role in helping consumers reduce FLW and in promoting sustainable consumption. For instance, in 2012, retailers and retail associations across Europe signed a voluntary agreement to engage in awareness-raising initiatives on consumer waste reduction (Eurocommerce, 2013). Press, Web and television programmes – such as cooking programmes – can be useful media for this, among others. Training programmes can teach how to take advantage of leftovers, or of stems of vegetables and fruit peels for the preparation of sauces, spices and juices (see Box 21).

Other solutions will rely on the introduction of technical options for consumers, such as better, smart packaging, or the introduction or development of the “doggy bag” practice in restaurants.

Reducing consumer waste could require government interventions and the support and cooperation of the food industry itself, such as improving the clarity of food date labelling and advice on food storage, or ensuring that an appropriate range of pack or portion sizes is available that meets the needs of different households (Parfitt, Barthel and Macnaughton, 2010; Kessova, 2013).

Finally, the reduction of consumer waste can give way to reallocation of spendings on food. For instance, as evidenced in the United Kingdom (WRAP, 2014), consumers spent a share of the FLW reduction-related savings on food expenditures by “trading up” to higher-value foods. There is therefore a way to associate retailers and producers in supporting consumer food waste reduction while maintaining the levels of sales.

Box 21 Cozinha Brasil (Kitchen Brazil): making the most of the whole of fruits and vegetables and of their nutritional properties

An initiative that deserves attention and that is being supported by FAO is a programme developed by SESI – an organization that gathers the Brazilian industry stakeholders, named *Cozinha Brasil* (Kitchen Brazil). The purpose of this programme is to teach notions of the full use of the food to poor families in Brazil and also to cooks in workers' and students' cafeterias everywhere. Kitchen Brazil started its activities in 2008 and has a fleet of 33 trucks equipped with experimental kitchens, nutritionists and a classroom where free courses are given to the general public and to food and nutrition trainers and educators. The trucks travel to isolated rural areas and poor neighbourhoods of large cities, and stay at these locations for four or five days teaching recipes such as papaya juice with orange peel, pink risotto (beet stems, stalks and peels of carrots), pizza with leftover rice, macaroni pie, banana pies making use of banana skin, etc. Through exchange and training, Kitchen Brazil has implemented similar projects in Uruguay, Guatemala, Honduras, El Salvador and Mozambique.

Source: http://www.sesipr.org.br/cozinhabrasil

3.2.9 Give value to surplus “saved” food

As shown above, the standardization of the products offered to consumers is a major cause of FLW in modern retailing systems. In traditional systems, products gradually lose their economic and exchange value along with their quality, as defined in Chapter 1 by the FLWQ concept. They are generally still sold or exchanged, but at gradually lower prices. For instance studies conducted by FAO in Kenya on several products report different selling prices reflecting different levels of FQLW (FAO, 2014c). In modern, standardized systems, products are rather defined as marketable or not. They “suddenly” lose all their economic value when they are no more of the quality considered as marketable – which is often not linked to their edibility – as illustrated by the confusion on date labelling. Products close to date limit could be sold at a discount rate. However such a discount system is not viable if the store or retail business model is based on emphasizing quality and freshness (Silvennoinen *et al.*, 2012). Alternative distribution systems can aim to give them a value. In the United States of America some retailers sell such products at discounted prices (NRDC, 2013). In a survey in Spain (MAGRAMA, 2013), more than half of the consumers answered that they would be ready to buy such products. Local markets can facilitate distribution of products with shorter shelf live or not respecting cosmetic standards of big retailers.

Surplus food redistribution has been promoted as a way of reducing FLW. Past studies have focused on the use of surplus food as if it were beyond the market mechanisms. This is challenged by recent research, which highlights that the practices are never independent of their market attachment, environmental and social relationships, inequalities in market powers along the redistribution chain, property rights and other legal issues affecting the efficiency and fairness of the redistribution (see e.g. Midgley, 2013)). .

In some cases, reducing FLW has obvious benefits when the effort to save is not too costly and the use of saved food is easy, for instance when it can be saved for a later use.

In other cases, efforts to redistribute the saved food could pose new risks regarding food quality, cost of transport and preservation, and potential impacts on local food prices. Redistribution of food requires additional labor, storage, examining and monitoring. If the saved food is too scattered, hard to identify the quality, or difficult to be transported to people in need, then the effort to save should be carefully evaluated.

Food banking

Food banking emerged as non-governmental initiatives in the form of associations collecting food to distribute it to people in need (Schneider, 2013a, b).

In traditional models of food banking, processors, wholesalers and supermarkets donate food that has little commercial value (over-runs in production, excess supplies, past sell-by or stock that does not move on the shelves), but is good and healthy for consumption. Many reasons can lead food chain actors to donate food to a food bank. Producers can donate products that are ripe and ready for harvesting, but whose market prices do not cover production costs. Processors can donate food that has faced problems in packaging, labelling or suffering from cancellation orders from buyers. Distribution and retail operators can donate food that is losing, or close to losing, its commercial value, such as being too close to the expiring date, or rendered unmarketable such as bruised fruit and vegetables. It can also donate surplus resulting from lower than foreseen sales.

Food bank models vary greatly between countries, notably in terms of the role and implication, the case being, of public authorities in the design, support and regulation of the system. Depending on local situations and history, food banks can be granted roles ranging from more traditional community support, on the one hand, to more formalized contribution to social protection on the other hand. These functions justify the involvement of public authorities, including to support and to provide specific rules and incentives for food banks, also to ensure that free food gets distributed to those really in need.

The good functioning of food banks requires a joint effort of food chain actors (to share information about the existence of surplus food and to separate and transport this food to a common redistribution point) and of the staff in the food banking association, very often working pro-bono. It also relies on the voluntary involvement of other specialties that have a secondary role in the food chain, such as logistics, information technology and legal services.

The role of national governments is essentially to guarantee an institutional environment that favours donations, with respect to tax incentives (Aiello, Eneo and Muriana, 2014), and to encourage civil responsibility. “Good Samaritan” laws (see Section 3.3.2) can also limit the liability of donating parties and encourage donation of food. Public authorities can also play a role in the regulation of such systems, for example to ensure that they are managed in a way that prevents free food re-entering the market. More recently, examples of privatization and government subsidization (direct and indirect) of food banks have emerged, for example in South Africa.

Food banking can help to raise awareness on FLW and hunger (Segrè, 2013) and demonstrates how individual and corporate social responsibility can help reduce FLW and contribute to food security and nutrition of people in need. Food banks do not act on the causes of FLW in retailing, or on the root causes of hunger. They do not aim to provide solutions for the many problems encountered in the retail sector, such as retailers passing costs of the system to suppliers and consumers, or retailers being reluctant to dismiss practices leading to propose excess food in the stores with respect to real consumer demand (Riches and Silvasti, 2014). In providing a means to give to edible food a value that would have been lost, food banks serve as a "second best" solution in a context where there are substantial losses of edible food in retail, together with populations unable to afford their food.

The large extent of food banks and their importance in terms of access to food for large segments of the population in some countries – such as in the United States of America, "Feeding America" supporting 37 million people, and in Europe 5.2 million people reached by the European federation of food banks (Schneider, 2013a, b) – give to food banks *de facto* a social protection role, supported by retailers and consumers, often with public contribution, leading to improved food security while promoting reduction of FLW. This highlights the importance of good governance of food banks. The interest and support by public regulation and public authorities testifies the role that food banks can play, if properly managed and governed, to contribute to food security, in providing food for people in need and in reducing FLW.

3.2.10 Valorize by-products, side streams and non-used food

Within the food processing sector, substantial parts of the raw materials that enter the factory are ultimately traded as by-products. Utilization of these streams for food would require alternative (and generally technically more complex) processing to the chains' primary product.

Hence, a large part of these side streams is only poorly valorized: for animal feed, technical applications and fertilizer production (through composting).

The production of fresh fruits, vegetables and root cuts involves numerous phases: pre-cooling, washing and disinfection, peeling, trimming, deseeding, cutting to specific sizes, sorting defects, dipping, drying, storage, packaging, labelling and distribution (James and Nagramsak, 2011). Industrialization of these stages can create opportunities for better valorization of by-product production of juices and jams (Verghese *et al.*, 2013), as feed, for bioenergy production and/or compost, especially when localized in rural areas. In such cases, it can also reduce costs of transport and reduce urban waste.

The livestock sector could use more of the industrial and catering reflux of foods which cannot be redirected to human consumption through redistribution and food banks, provided they do not present any health risk when used as feed. Such foods include for instance bread, broken biscuits, and products safe to eat but with an appearance default, incorrectly packed products (wrong filling, damaged package) and food leftovers of big events. The success depends on a number of practices, processes and policy parameters, such as safety, traceability, clear legal status of materials and operators, and cost.[23]

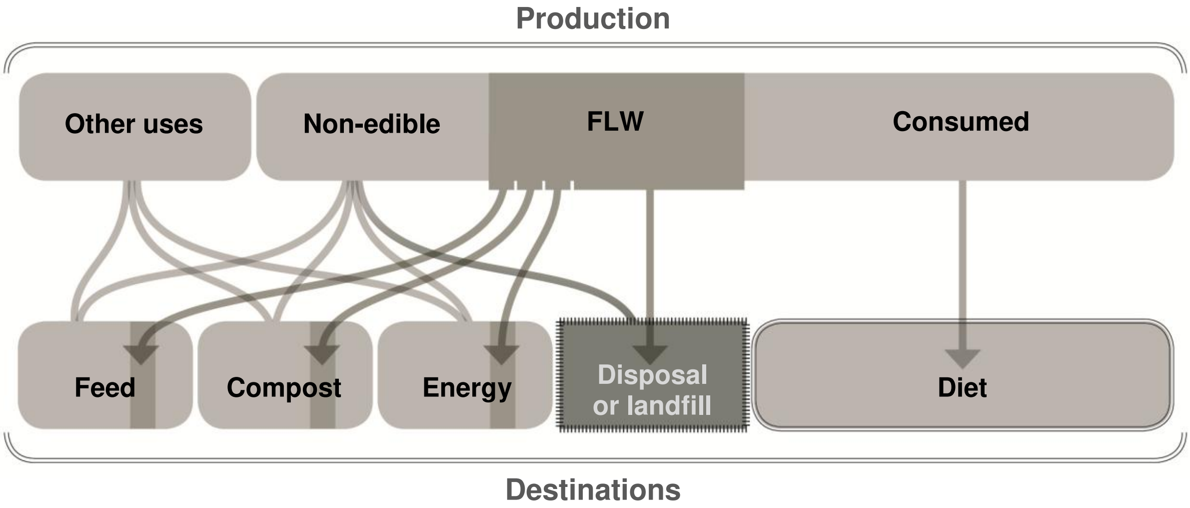
Technical innovations can enable to valorize co-products and side streams as food or feed (Box 22).

The development of closed-loop supply chain models (WEF, 2010, 2014) is another means to coordinate all actors for concerted actions towards FLW reduction. In such models, losses or waste of all forms are fed to the extent possible back into the value chain (such as packaging waste being re-used). Food graded as lower quality for cosmetic reasons and food that is surplus to retailers or manufacturers would be made available through alternative routes (as cheaper alternatives), while food waste would be utilized as a by-product, e.g. in providing energy from waste using the appropriate technology. Food waste side streams could also be used to feed insects having a potential for nutritious feed or food (see Box 23).

Food-related waste (including edible and non-edible parts) represents an important proportion of total waste. In rural areas, it can be used easily as feed or organic fertilizer, either directly or through compost. In urban areas, it is often not valorized and constitutes an important part of waste, which is a growing concern. Organic waste is also an important source of methane when sent to landfill. After being sorted and treated, organic waste can be valorized and transformed into compost and methane valorized as energy, both reducing the environmental impact of FLW, and with economic gains.

[23] http://ec.europa.eu/dgs/health_consumer/dgs_consultations/docs/ag/summary_ahac_05102012_en.pdf

Figure 6 Schematic representation of agricultural production and destinations



Agricultural production can be directed to food and non-food uses. Non-food uses include feed, compost and energy uses. The share of production intended to food can be divided in three components: the part consumed as part of the diet; non edible parts are directed to feed, compost, energy or landfills; and FLW that often end-up in landfills, but can also be directed to feed, compost or energy.

Box 22 Examples of side stream valorization

Rice bran utilization in india

India is a leading producer of rice and a large quantity of rice bran was produced in hullers and traditional rice mills but the quality of rice bran produced was poor due to high fatty acids. The rice bran produced was not pure and mixed with rice husk particles and was used mainly for boiler feeds and for the soap-making industry. R&D work was carried out in national laboratories and other institutions to stabilize the rice bran in order to recover valuable rice bran oil rich in antioxidants, which could be used for edible purposes. The process of recovery of edible oil from rice bran is by solvent extraction process and during this process a large number of valuable by-products are obtained. This has boosted the value addition to rice bran utilization in the country and presently a major part of rice bran that is produced in rice mills goes for extraction purposes. Edible grade rice bran oil is presently used as cooking oil and also being marketed as ‘health oil’’ in combination with other edible oils.

Gelatin production in the Netherlands

Confidence in traditional sources of gelatin (among others bovine hides and bones) was seriously damaged by the BSE breakout. The increase in gelatin prices has been a trailblazer for alternative production processes. A successful example is the Dutch company Ten Kate Vetten; their production process (primarily aiming at extracting fats from pig slaughter by-products) was innovated so that high-quality gelatin can be isolated from their processing water. The (mild) fat extraction process furthermore enabled valorization of other protein products in pet feed. The key success factor was the development of a patented innovative process that enabled valorization of high-quality gelatin, while an external factor was the market demand for gelatin from a safe source due to BSE breakout.

Protein recovery from the starch industry in the Netherlands

Recently, the Dutch potato starch processing company AVEBE started recovering proteins from what was previously considered wastewater (in a new company called Solanic). Based on the average annual throughput (2.5 million tonnes of potatoes, grown on 55 000 hectares, delivering 700 000 tonnes of starch), the AVEBE/Solanic production potential is estimated at 25 to 30 000 tonnes of high-quality potato proteins. This new, by-product-based source can replace 15 000 ha of protein crop cultivation (average protein productivity is about 2 tonnes/hectares (Vereijken and Linnemann, 2006).

Box 23 Transforming waste in nutritious food and feed: the potential of worms and insects

Approximately 1 900 insect species are eaten worldwide, mainly in developing countries. They constitute quality food and feed, have high feed conversion ratios, and low environmental impacts. Conversion of organic refuse into compost by saprophages such as earthworms and microorganisms is a well-known procedure. A number of insect species such as larvae of the black soldier fly, the common house fly and certain mealworm species can be grown on organic side streams, reducing environmental contamination and transforming waste into high-protein feed that can replace increasingly more expensive compound feed ingredients, such as fish meal. Most of the experiments have been done on a laboratory scale. Developing and standardizing mass-rearing techniques on an industrial scale could become a new economic sector. However, there are still a number of challenges, both biotic and abiotic, that need to be addressed, e.g., rearing, automation, and safety issues related to pathogens, heavy metals, and organic pollutants.

Source: van Huis (2013).

3.3 Promoting and enabling individual and collective change

As we have seen in the previous sections, there are many causes of food losses and waste, from different actors, at different levels. Some of the causes, as discussed in Section 3.1, may be solved by technical, actor-level solutions. Some other solutions are found at meso-level and require collective and concerted actions. But often, to concretize, these meso (and also the micro-level) solutions need an enabling environment.

As we have seen, many of the causes of FLW – and therefore the appropriate solutions – are due to behavioural or economic choices, which seem rational at one stage of the chain, but may lead to FLW when the rest of the food chain is considered. For example, the decision of a farmer to plant a larger field at the expense of not necessarily harvesting the whole of it depending on market conditions; the decision of food chain agents to overbuy on food with respect to potential sales and their variability; supermarkets needing to show a situation of abundance of products to attract clients, etc.

When considering FLW reduction, there is a need to find a “substitution” to the different “functions” that the actions that end up in creating FLW in the first place “ensure” for the different actors.

There is also a need to consider some effects of food loss reductions on the food system at large. For instance, FLW achieved in the initial stages of the production chain could lead to “indirect” effects on the other stages, down to the consumer, and in a system as a whole. Some studies (Rutten, 2013; Godfray *et al.,* 2010) point out that the reduction of losses at production stage, in providing a greater supply of food downstream, could simply raise the waste downstream in the food system, and that the consumer – attracted by a greater offer of products and a possible drop in prices – would have access to more food and be more likely to waste. In other words, without accompanying measures down the chain, and in general a change of “mentality” there is no guarantee that FLW reduction at post-harvest level will not translate into an increase of food waste at consumer level.

In this section, we show how macro-level solutions can help in tackling individual and collective causes of food losses and waste, including individual and collective ones.

First there is a need to address the underlying economic behaviour fundamentals that may lead to FLW, and to find out who wins and who loses from FLW reduction actions, in order to possibly share costs, or address “winners and losers” constraints. This is explored in Section 3.3.1.

Second, proper promotion, support or incentives to FLW reduction can be crafted at policy level. Policies can make use of incentives (including taxes), regulation and coordination of actions, as well as providing overall directions or vision, and determine priorities among actions. Policy measures that can impact FLW (or trigger FLW reductions) can take diverse forms and elements can be found in diverse areas and policy sets, sometimes in other sectors. It can also take the form of dedicated FLW policies. This is explored in Section 3.3.2.

Finally, as Section 3.3.3 will show, multistakeholder initiatives can play an important role to raise awareness, advocate and bring all actors together to decide and implement FLW reduction actions from national to international levels.

3.3.1 Consider costs and benefits to overcome "winners and losers" constraints

The existence of FLW implies costs for various actors, from producers with foregone revenues, to consumers with useless spending. Considering costs–benefits aspects is essential in order to overcome "winners and losers" constraints to individual and collective action.

But the mere existence of a potential to reduce losses, and of technical solutions (technologies, portfolio of measures), at individual and also at collective level, such as those presented in sections 3.1 and 3.2, is not enough to trigger their implementation. Actions to reduce FLW at different levels are not free of cost. Also, when one compares a situation with food losses and waste with a situation with less food lost or wasted, winners and losers may appear. Finally, FLW reduction impacts (and related costs) propagate along the chain, with potentially positive effects for some and negative effects for others.

As a consequence, when there is a solution or measure taken by any decision-maker to reduce FLW, the costs and benefits are often borne not only by the decision-maker but also by other stakeholders along the food chain and in other sectors related to the food markets.

Whether, for each actor, and for the society as a whole, the benefits of FLW reduction outweigh the costs of the reduction measure are key questions.

From an economic point of view, when the marginal benefit of FLW reduction exceeds the marginal cost of the measure, it might be optimal to just stay with the losses. As a result, there will always be a certain amount of food loss and waste (Stuart, 2009), and we have also seen in Chapter 1 that ensuring the "stability" dimension of food supply might lead to accepting a certain level of FLW.

What is the amount of food losses and waste, which is "optimal" from the point of view of society and food security? Is there a point where FLW reduction measures prove too costly with respect to the benefits? What actions, providing the best opportunities need to be pursued in priority? What are the stages where the costs occur and what are those which benefit from the measure?

Answers to these questions, decisions on implementation of FLW solutions and set-up of FLW reduction policies would deserve to be based on sound cost–benefit analysis, assessing impacts, building scenarios and evaluating the situation of winners and losers, so as for example to ensure that the right incentives or corrective measures are put in place. Models of impacts are very useful to evaluate *ex-post* changes and transition to a new organizational or technological pattern (HLPE, 2013).

Several issues bring additional layers of complexities to any cost–benefit analysis on FLW:

1. Costs of actions (e.g. investments to reduce FLW, in harvesting, handling, storage, distributing, marketing facilities, etc.), or costs induced by the FLW reductions may directly fall on certain actors, or collectively on a subgroup of them, while corresponding benefits will bear on others. The reduction might be profitable for some actors and for society as a whole, but how to ensure proper incentives for action for those who are bearing most costs, and how to compensate for actors negatively impacted by FLW reduction actions?
2. Actors along the food chain react and adjust their behaviour in response to the consequences of FLW reduction.[24] For instance, market supply and conditions on the market may change. This might modify the initial assumptions on costs and benefits. How exactly will producers, various actors in the middle stream of the supply chain (e.g. processors and wholesalers) and downstream, retailers and consumers, react? How to account for this in the reasoning?
3. Many of the benefits of FLW reductions are positive externalities (reduced pressure on the environment, etc.). In the absence of a corresponding pricing system (integrating negative externalities), how to account for those in the analysis, to be sure it is not distorted?
4. Social, cultural and health (food safety) constraints may limit the amount of FLW that actors may actually reduce. How to account for those social, cultural and health costs and benefits of FLW reduction?

[24] See for instance Section 3.2.9 for factoring in consumer behaviour.

5. Costs and benefits are both uncertain, including those of actions at macro level, such as policy interventions. How to account for uncertainty to calibrate the appropriate level of action?
6. FLW is not a single variable to optimize: it concerns various foods, involves various stages of the supply chain, and potentially a wide range of measures at different stages and levels (micro, meso, macro). The level of information and data ideally required is considerable, whereas currently the information available is very limited and scarce.
7. Finally, there is a need to factor in the economic aspects of FQLW, as a loss in quality is often linked to a loss of value of the produce; and as actions reducing FLW often also reduce FQLW and thus increase the value of the product.

All these elements explain why cost–benefit analysis on food losses and waste is extremely challenging. It explains why there are so few studies available, and mostly in the form of case studies circumscribed to a specific product and technology and in a particular local context.[25] Those case studies are point-based studies and do not document the important effect that "scaling up" might have to lower the costs. And they are obviously not replicable to other very diverse regional and national contexts. And they lack comprehensiveness, taking all measures, all products, all actors into account. There have been some recent attempts to undertake comprehensive cost-benefit estimates at the level of the United Kingdom in terms of real savings and in the EU for a FLW reduction scenario (see Box 24), but results remain fragile. By extension, no global study is available.

Box 24 Impacts of FLW reduction along the chain: an economic modeling exercise.

Rutten *et al*. (2013) used a general equilibrium model to examine the likely impact of reducing food waste by households and in retail in the EU. This builds on a simplified theoretical economic framework of food losses and waste reduction and welfare impacts on producers and consumers. According to the simulation, a reduction of consumer food waste by 40 percent – assuming this reduction is at zero-cost – would result in household welfare increase and annual savings of €123 per person, or 7 percent of the average EU-household budget spent on food. Non-food sectors would benefit from the reallocation of saved household expenditures on food, and food sectors would lose. However, assumptions of a zero cost of food waste reduction may lead the modelling to overestimate the real impacts.

These results have to be taken with caution as there are known limitations to the use of the currently available portfolio of economic modelling tools (e.g. market simulation models, partial equilibrium model, general equilibrium models) to perform such analyses: difficulties to appropriately capture changes in the technology and in the behaviour of actors, failure to account for "physical" food fluxes along the food chain, difficulty to account logistic and spatial issues, difficulty to tackle situations of imperfect competition or existence of "big players" in a sector (HLPE, 2013).

The same lack of quantitative evidence holds for relationships between FLW and food prices, a key food security variable, particularly important for the poor. These relationships can be quite complex, and impacts go both ways.

First, the price of food is likely to impact FLW levels: the higher the price of food, the more care is taken not to lose or waste food. Low food prices are a disincentive for farmers to produce and also a disincentive for consumers to reduce waste.

Second, FLW levels can influence food prices by several mechanisms. At micro-level, initial investments and unit costs of FLW reduction measures and investments can act to push prices up.

At macro-level, reduction of post-harvest losses can lead to increases in market supply of food and in actors along the food chain being more resource efficient, which would result, everything else being equal, in lower prices for both producers and consumers. In situations of imperfect or traditional markets, often dominated by intermediaries, the food security benefit – through lower prices – of a reduction of losses at production and distribution stages would not carry over all benefits to the households, due to imperfect price transmission and eventually financial gains from the reduction in losses could be concentrated in a few middle chain agents with no benefit for the final consumer (Vavra and Goodwin, 2005). Lower prices in turn may also lead to consumers wasting more, creating a negative "counter" feedback loop to FLW reduction.

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[25] At micro-level, only a few techniques and practices are documented in terms of cost, such as evaporative coolers to extend the shelf life of food, plastic storage bags and small metal silos to reduce loss in storage, and plastic crates for handling and storage (Lipinski *et al.,* 2013).

The overall effects, relationships (and counter feedback loops) between FLW reduction and food prices remain therefore largely undetermined and ultimately will depend on the balance between technological, market and consumer behaviour factors, including product/food substitution issues both at the farm and at the consumer level.

Ideally, analysis of FLW reduction measures should consider potential winners and losers in the whole food system, whether or not the poor producers and consumers gain from FLW reduction. It should also consider how FLW was used (e.g. used as feed for animals) or disposed of. It should finally consider all the impacts of the proposed change to reduce FLW; see the example (Box 10) of change of food containers in Brazil.

Given the uncertainties depicted above, one no-regret measure, prior to implementation, is to seek to lower the costs of FLW reduction measures (or to increase their efficiency in terms of FLW reduction levels). FLW reduction starts by providing information and knowledge on solutions. Providing information and knowledge has its own costs, but lack of information and knowledge can increase the cost of adopting measures, hinder the ability to access technology and other measures. Government, public and private institutions could play important roles in providing immediate market and other information affecting an individual's decision-making.

3.3.2 Integrate FLW concerns in policies

Integrating FLW concerns in policies can take two ways, which are complementary: (i) integrate FLW concerns in all policies which can have an impact on them; (ii) devise a specific FLW reduction policy to address the interdependencies of actions that end up creating FLW.

Agriculture, the food chain and consumption are fields where numerous public policies interact: policies directed to agricultural development, investments, support to various food system actors, regulations of the food chain, fiscal policies, trade regulations, food safety and consumer protection regulations, social protection and food security policies, and sustainable development policies and environmental protection policies, just to cite the main ones. This broad spectrum varies in orientation from country to country. Policies are also often key for data collection. We have seen (Section 2.2.3) that there is still little consideration for impact on FLW of policies of diverse nature that shape or regulate the food system. Conversely, when looking at country-level situations, integration of considerations in diverse policies in order to reduce FLW is currently still limited. Finally, there are few policies that are specifically aimed at fighting FLW.

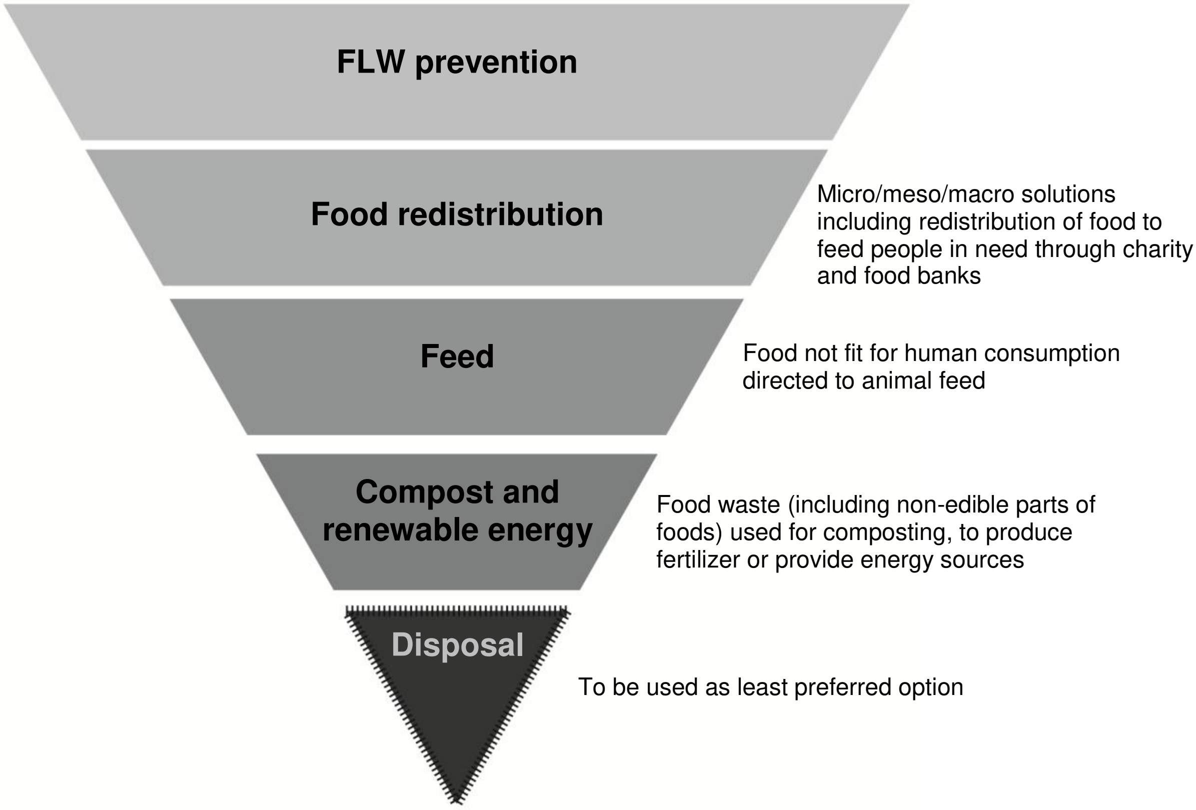
In this section, we review the current state of policies that have an impact on FLW. We make a particular case of waste policies, and of those policies (or component of policies) put in place to prevent specifically *food* losses and waste.

Waste policies are the first having an immediate direct link to food losses and waste. In OECD countries (OECD, 2014), existing legal frameworks with a FLW component are mostly focused on waste management and environmental concerns in general, and aspects of prevention and improved re-use of waste, all waste taken into account, the food parts within the waste being only one aspect of the problem.

One of the roles of policies is to set priorities or to coordinate actions of various actors or sectors. One of the important dimensions of such priorities is to give clear directions among the "competing" uses of food left over. Many "food use hierarchies" have been developed in the literature.[26] In line with an overall pattern of waste management, they all more or less follow the same structure, depicted in Figure 7, which aims to: first, support FLW prevention; second, facilitate the distribution of still edible but not marketable food such as by means of food banks or other institutions to that effect (see Section 3.2.8); third, for what is left, use as animal feed; and fourth, use as compost and/or energy (see Section 3.2.10), and using disposal in landfills as the least preferred option.

[26] Such as the Food Waste Pyramid for London, presenting a hierarchy of approaches to tackle food waste, in order of priority (http://www.feeding5k.org), or the food recovery hierarchy developed by the US Environmental Protection Agency. Other examples are the Netherlands Ladder of Moerman, OVAM (Public Waste Agency of Flanders)'s food waste hierarchy, Food Drink Europe's food waste hierarchy. It prioritizes reduction at source and presents a list of preference for use, re-use, recycling and waste treatment. The US-EPA and London hierarchy are both rough simplifications of the flow of food residues, presented to make the communication to the public easier.

Figure 7 A food-use-not-waste hierarchy to minimize FLW



Source: adapted from www.feeding5k.org

FLW as an element of waste policies

Waste policies often tend to apply to food the same "logic" as applied to all other waste in terms of defining its objectives and the hierarchies of priorities. Though there are some subtleties across countries, a general pattern can be found in the hierarchy of such waste policy objectives: (i) avoid waste generation; (ii) manage waste as a resource; and (iii) ensure efficient, safe and environmentally sound treatment, reuse, and, ultimately, if needed, disposal of waste (see Figure 7).

However, waste policies often do not explicitly deal with food. For instance, unspecified taxation of general waste does not specifically provide an incentive to reduce food waste.

Some impact on FLW can be found in waste policies promoting waste separation, such as in Scotland since 2014, which has imposed separation of food waste from other waste, enabling its valorization for energy in anaerobic digesters and/or compost. These policies are generally associated with landfill bans (such as in the Republic of Korea, Norway, Sweden) or landfill taxation for organic or biodegradable waste (as in the United Kingdom).

The Republic of Korea has added concrete FLW measures and regulation to its waste policy. From 1995, the Government started to collect food waste separately from other municipal waste. In 1998, the Food Waste-to-Resource Plan was established to reduce discharge of food waste by more than 10 percent and recycle as a resource more than 60 percent of the discharged food waste until 2002.

Landfill of food waste has been prohibited since 2005 (OECD, 2014). In 2010, the Master Plan for Food Waste Reduction was put in place, a nationwide policy that introduced a volume-based food waste fee system, charging residents according to the weight of food thrown away, with the official goal to eventually reduce total national food waste by 20 percent, thereby cutting waste treatment costs. This included investments in high-tech public waste bins, which open after household identification through radio frequency identification cards (RFID) containing the user's name and address. The bins give a numerical reading of the waste's weight and computes disposal cost, billed monthly to households. According to the Korean Ministry of Environment, based on the monitoring of the performance of the pilot RFID system from January to May in 2012, on average, food waste has been reduced by 25 percent. The Government will scale up the RFID system and spread across the country, with national funding to support local governments in the transition (OECD, 2014).

In Japan, a law for the promotion of Recycling and Related Activities for the Treatment of Cyclical Food Resources aims at preventing food waste and at promoting recycling of food waste into animal feed and fertilizers as well as energy recovery. This legislation stipulates a hierarchy for food waste treatment: first reduction at source, then use for feed, then for heat recovery, and reduction in weight by drying (OECD, 2014).

In Ireland, a Household Food Waste Regulation promotes the segregation and recovery of household food waste, directing separated food waste to composting, and imposing obligations on waste collectors as well as on households. Furthermore, through the Waste Management Regulations of 2009, the catering sector has obligations in terms of segregation and processing of food waste (OECD, 2014).

One important characteristic of waste policies, such as the German example shows (Box 25), is their decentralization: the overall framework and objectives are generally set at national level, but management, funding and implementation is often operated under the responsibility of local authorities and municipalities that oversee waste collection, management and recycling services.

Box 25 The German National Waste Reduction Programme of 2013

The German National Programme of 2013 ("*Abfallvermeidungsprogramm des Bundes unter Beteiligung der Länder*") to reduce waste recommends 32 measures to be initiated by many stakeholders: local authorities, state governments, the federal government, public authorities and private firms. It has specific food losses and waste components (measures 17 and 28), and a specific programme "Too good for the bin" ("*Zu gut für die Tonne*") highlighting the need for concerted actions all along the food chain. The catalogue of measures includes research in the field of loss-reducing processes, development of benchmark indicators, awareness campaigns and dissemination of information, advisory services for enterprises, cooperation among enterprises to reduce loss and waste, voluntary agreements between stakeholders and concerted actions between food industry and retailers.

Source: Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (http://www.bmub.bund.de).

FLW as an element of food policies: food labelling rules, food safety rules, food standards rules, food redistribution policies and food subsidies

Given the lack of formal definitions or standardization across date labeling policies and practices (see Section 2.2.4), and as the unreliable signal it can give to consumers is a worldwide issue, the Codex Committee on Food Labelling, following a proposal by New Zealand, is currently considering the possibility of revising its General Standard for the Labelling of Prepackaged Foods to address issues on date marking. The European Commission wants to help consumers cut food waste by making "best before" and "use by" dates (see Section 2.1.4) clearer on the packaging and setting clearer labelling rules for consumers, often misinterpreted due to the lack of understanding on the distinction between the "best before" date (quality criteria) and the "use-by" date (safety issue).

Good design and implementation of food safety regulations and procedures can play an important part in reducing food losses and waste at national and international level. In some countries, there is a need to update and revise the existing legal framework regarding food quality and safety. Simplifying regulations and procedures can be key. Regulations governing food standards are often lacking or outdated. Good food control policy and institutions can support actors in implementing good practices to reduce safety risks and improve quality. Increased reliability of food safety institutions and practices at national and international levels can reduce control delays, increase the trust of all actors in the quality and safety of food products, facilitate trade and reduce waste. Improving design and implementation of intraregional trade regulations would reduce FLW due to delays, breaks of cold chain or additional handling (FAO, 2013d).

In 2008, the European Commission approved the phasing out of regulations on marketing standards on the size and shapes of fruit and vegetables (EC, 2008): it reduces the aesthetic requirements for many fruits and vegetables, bringing more choice to consumers and preventing fruits and vegetables with slight aesthetical abnormalities from being thrown away.

At national level, food safety considerations can sometimes hinder donation of food, because donors may fear being reliable for any consequence if the food ends up being unsafe or harms the beneficiary. The United States of America and Italy have a “Good Samaritan” clause in food donation acts. For instance, the 1996 US Good Samaritan Food Donation Act encourages the donation of food to non-profit organizations for distribution to people in need. It protects the donor from liability should the product donated in good faith end up harming the recipients, setting a floor for “gross negligence” for voluntary and conscious misconduct.

Some authorities have incentivized the redistribution of food to people in need by integrating relevant disposition in their fiscal policies. The EU allows its members to exempt from value added tax the food donated for charitable purposes (VAT directive, Articles 16 and 74). In the United States of America, where food redistribution is well developed, the Internal Revenue Code 170(e)(3) provides enhanced tax deductions to businesses to encourage donations of fit and wholesome food to qualified non-profit organizations serving the poor and needy. Qualified business taxpayers can deduct the cost to produce the food and half the difference between the cost and full fair market value of the donated food. The US Federal Food Donation Act of 2008 specifies procurement contract language encouraging federal agencies and contractors of federal agencies to donate excess and otherwise discarded wholesome food to eligible non-profit organizations to feed food-insecure people in the United States.

Within food policies, particular attention has been given to FLW of subsidized bread, such as in Egypt and Iran (World Bank, 2010; FAO, 2013d; Shahnoushi *et al*., 2013) and the way to reduce them by fine-tuning the policy itself, and the related control and interventions, as the example of the reform of the complex Baladi bread supply chain in Egypt shows (USDA, 2014).

Specific policies to prevent FLW

Some governments have started to define specific targets for FLW reduction: the United Kingdom (2000), Republic of Korea (2008), Japan (Food Recycling Law in 2001), the Netherlands (2009), France (2013), Spain (2013) and Austria (2012). Sweden has set a national target that half of the food waste from households, shops and restaurants needs to be separated and treated biologically and that 40 percent is handled for energy recovery (OECD, 2014).

“Specific” FLW reduction policies can use economic instruments: taxes for waste disposal and treatment (landfill and incineration), pay-as-you-throw systems, producer responsibility schemes, or “softer” measures such as communication and awareness raising, or the creation of dialogue platforms among actors (see Section 3.3.2 for some examples).

They can also take the form of assisting the post-harvest sector. There are few examples of integrated post-harvest losses reduction policies, pointing to this area as a major policy gap within agricultural development. In China, several policies aiming to improve the efficiency of the agricultural sector specifically address post-harvest losses, especially storage (Liu, 2014). Another example is the 2011 Rwanda National Post-Harvest Staple Crop Strategy and Action Plan, put in place to coordinate efforts by several ministries and agencies to more effectively address issues of post-harvest staple crop loss. The strategy[27] is a policy framework that assists with strengthening the harvesting, post-harvest handling, trade, storage and marketing within staple crop value chains in Rwanda, in an effort to improve markets and linkages for farmers, and reduce post-harvest losses. Its Strategic Axes of Intervention include:

1. Information available for public and private sector decision-making.
2. Efficient and equitable transport systems across staple crop producing areas.
3. Reduce staple crop post-harvest losses at producer and first aggregator level.
4. Strengthen private enterprise in staple crop value chains.
5. Increase private sector post-harvest investment.
6. Enhance structured staple trade.
7. Transparent strategic grain reserve supporting food emergency needs and liberalized markets.

FLW reduction policies, when they exist, are often part of broader strategies towards resource efficiency, sustainable production and consumption, and the sustainability of food systems. In that

[27] http://www.minagri.gov.rw/fileadmin/user_upload/documents/Publications/National%20Post%20Harvest%20Strategy%20-%20Nov%2022.pdf

context, FLW targets are driven by other objectives such as the reduction of general waste in volume, or resource efficiency (by analogy to the energy sector, "more with less").

For instance, the European Commission (2011) has set a target to reduce FLW by 50 percent in 2020 as part of the flagship resource-efficient Europe, the initiative under the Europe 2020 Strategy (EC, 2011), which calls to "*find new ways to reduce inputs, minimise waste, improve management of resource stocks, change consumption patterns, optimise production processes, management and business methods, and improve logistics*", with an implementation "roadmap" highlighting the food sector as a priority area for action, calling for "*incentives for healthier and more sustainable production and consumption of food and to halve the disposal of edible food waste in the EU by 2020*". EU Member States have been encouraged to include food waste prevention policies and targets in their National Waste Prevention Programmes.

Another example is the recent Chinese circular issued in March 2014 by the General Office of the Communist Party of China Central Committee and the General Office of the State Council. According to Vermeulen (2014) "*The Chinese have a deep history and relation to food... (Food waste in restaurants is, ironically, emblematic of the value placed on food – providing more than enough to guests shows your respect to them). It also translates into the sincere actions by the state to reduce waste*" (Vermeulen, 2014). The circular targets ending dining waste of official events, promoting frugal meals in all canteens, reducing government and public institutions' spending on official and business meals, particularly food banquets and receptions, pursuing healthy food consumption patterns, enhancing efforts to reduce FLW in all stages along the food supply chain, advancing reutilization of discarded food, intensifying awareness raising and education, speeding up the legalization process to set up new laws and regulations against food losses and waste, and strengthening supervision and inspection of FLW.

These FLW policies often focus only on some specific segments of the FLW problem (part of the food chain, or level of solution), which makes them well targeted but not necessarily comprehensive.

Specific policies to prevent FLW are often combined with national multistakeholder initiatives (see next section).

3.3.3 Mobilize all actors and consumers for awareness and action

There is a growing number of initiatives around the world that focus on reducing FLW, at national, regional and local levels. In this section we list some of these initiatives, which are very diverse in terms of scope, or also with regard to their multistakeholder character, or their relation to an existing underlying policy framework: the ForMat project in Norway (see Box 26), the Sustainable Food Alliance in the Netherlands (see Box 27), "More food, less waste" in Spain (MAGRAMA, 2013), "National pact against food waste" France (MAAF, 2013), the US Food Waste Challenge, the UK Courtauld Commitment at national level; at regional level with the FUSIONS research project in Europe; and at global level with the SAVE FOOD initiative.

They generally gather public and private actors, in a multistakeholder setting, often with a significant engagement of the private sector.

The US Food Waste Challenge, which was launched by the US Department of Agriculture (USDA) and the US Environmental Protection Agency (EPA) in June 2013, calls on entities across the food chain to reduce food loss and waste in the United States of America, recover wholesome food for human consumption and recycle discards to other uses including animal feed, composting and energy generation. The goal of the US Food Waste Challenge is to lead a fundamental shift in how food and food waste is managed in the country. To join the Challenge, participants list the activities they will undertake to help reduce, recover or recycle food waste in their operations. The challenge includes a goal of 400 partners by 2015 and 1 000 by 2020. The US Food Waste Challenge is bolstered by the EPA's Food Recovery Challenge, which offers participants access to data management software and technical assistance to help them quantify and improve their sustainable food management practices.

Again in the United States, the Food Waste Reduction Alliance, established in 2011, brings together 30 business groups from the food industry, the food retail sector and the food service industry to reduce the food waste generated, increase food donation and recycle and divert food waste from landfills (OCED, 2014).

Box 26 Collaborative project in Scandinavia

The ForMat project is a business-driven initiative to reduce FLW in Norway. It is funded by a combination of private sector and state organizations working within the food and beverage industry, retailers and suppliers and environmental protection organizations. A three-year project (2010–2013), the end goal is to reduce food losses and waste by 25 percent by not only industry players, but end-consumers as well.

The ForMat project consists of four parts: (1) quantitative analysis; (2) network cooperation between businesses in the food sector; (3) communication and dissemination; and (4) actions to reduce food losses and waste.

The quantitative analyses were finalized in 2013. The data was collected using systematic uniform methods in order to ensure the best possible comparability over time. The ForMat project is quite unique in analysing trends in the development of food losses and waste over time. The project also demonstrated how consumer behaviour and attitudes regarding food waste change over time, and how this may help to reduce food waste in Norway (Hanssen and Møller, 2013).

A collaborative approach in Scandinavia is ongoing to reduce food losses and waste and is supported by the Nordic Council of Ministers (Marthinsen *et al.,* 2012; Stenmarck *et al.*, 2011).

Box 27 Alliance for supply chain collaboration, joint strategy, action plans and R&D

The Sustainable Food Alliance was launched in 2012 as a partnering coalition to improve sustainability in the Dutch agrifood chain. Members are the main organizations covering farm to fork: the Dutch Federation of Agriculture and Horticulture, Dutch Food Industry Federation, Royal Dutch Hospitality Industry, Dutch Federation of Catering Organisations and the Dutch Food Retail Association.

The Sustainable Food Alliance and the Ministry of Economic Affairs together developed the Sustainable Food Agenda 2013–2016 (SFA, 2013). Reducing food losses and waste and optimizing waste streams is a priority area, with the ambition to also contribute to the government objective to reduce FLW by 20 percent in 2015. The Alliance launched 2014 as the “year against food wastage”. The main activities concentrate on the increase of consumer awareness, organization of a help desk for industry to optimize waste streams, with the objective of supporting the transparency of the food chain by collecting reliable data on FLW.

The collective retail and food industry sector invested in 2012–2017 in a pre-competitive research programme to design and develop a decision support system (DSS) for integral cost–benefit analysis, with the main goal of facilitating the implementation of business cases for solutions in supply chain cooperation. The DSS will simulate the impacts and effects of solutions and interventions to reduce food FLW for perishable products, such as salads, fresh meat, bread and dairy products.

Source: SFA (2013)

One successful example targeted at food and packaging waste is the Courtauld Commitment[28] in the United Kingdom, one of the first initiatives on food waste, which started in 2005. It is a government-funded voluntary agreement aimed at improving resource efficiency and reducing loss and waste within the country’s grocery sector, including food and packaging. It supports the government’s policy goal of a “zero waste economy” and climate change objectives to reduce greenhouse gas emissions. WRAP, a UK not-for-profit company acting on waste, is responsible to work in partnership with leading retailers, brand owners, manufacturers and suppliers who sign up, and to support the delivery of the targets, among others, by helping manufacturers, the grocery sector and households to reduce FLW, such as through improving packaging design and recycling. To estimate household waste, WRAP uses household food waste data collected by local authorities and food waste composition studies. Phase 1 (2005–2009) achieved a UK-level reduction of 13 percent of food related (*including packaging)* waste,[29] from 8.3 million tonnes to an estimated 7.2 million tonnes. Phase 2 (2010–2012) led to a further reduction of 10 percent of the impact of packaging, a reduction of 3.7 percent of food waste at household level, and a reduction of 7.4 percent of losses in the supply chain. Phase 3 was launched in 2013 and aims at a further 5 percent FLW reduction in households (and 3 percent in grocery supply chains) by 2015. A range of factors explain this result: success of the Courtauld

[28] Source: http://www.wrap.org.uk

[29] These data include packaging and also “unavoidable” discards (inedible parts, such as meat bones, egg shells, pineapple skin, tea bags, etc.); both do not enter in the definition of FLW used in this report. Waste of edible parts of food was reduced by 18 percent. This shows that reducing FLW *stricto sensu* can lead to co-benefits in reduction in packaging waste and also on discards of other, non-edible, parts of produce.

Commitment, but also increasing food prices, difficult economic conditions and changes to food waste collection systems. Determining the extent to which each of the various factors have played a role is extremely challenging. A quantitative modelling study by Parry (2013) examined the interplay between macro factors such as food prices, economic conditions and the raising awareness on food waste, suggesting that increasing food waste awareness (as measured using the proxy of media mentions) accounted for between 29 and 40 percent of the observed reduction, with higher real food prices and low growth in real incomes accounting for the rest.

In recent years, many countries and initiatives have focused on raising consumers' awareness to the importance of FLW reduction (see Section 3.2.9). We give a few examples of them in Box 28.

Other national-level multistakeholder initiatives have been launched in Japan, with a working team composed of manufacturers, wholesalers and retailers to review and improve its business practices in order to reduce food waste; in Spain, including retailers and food banks operators to facilitate reuse and recycling of food (MAGRAMA, 2013); and in France to prepare the National pact to fight against food waste (MAAF, 2013).

Box 28 Campaigns against food waste

China: "Empty Plate" Campaign – This campaign draws people's attention to food waste. The campaign was initially targeted on public food consumption and reception and banquets. Anecdotal evidence suggests that since the start of the Campaign in January 2013, there has been a significant reduction in restaurant food wastage. It includes mobilizing public media, national level and state-run TV station CCTV as well as a number of TV stations at provincial level with a series of public advertisements against food waste.

Republic of Korea: "Half-bowl" Campaign and a New Container – This campaign encourages people to order half a bowl of rice to reduce food waste in restaurants. It was expected to reduce restaurant FLW by 20 percent by the end of the year. Some companies invented a new kind of food container, which adds an extra layer inside to exclude air and moist in order to slow down the rotting process.

Japan: Delivery Date Extension Experiment - Japan experimented on extending the delivery date to reduce FLW. Customs in the Japanese food industries requires a "1/3 rule", which says food products that exceed one third of the expiration time cannot be delivered to retailers. Participating companies will extend the food delivery date to half expiration time.

United Kingdom: Love Food Hate Waste - *Following this campaign in West London avoidable food waste decreased by 14 percent in just six months. The campaign and approach were developed using the "4 E's" behavioural change model:* enabling people to make a change; encouraging action, engaging in the community and exemplifying what's being done by others. *For households that reported they were aware of the campaign and other food-waste messaging and claimed to be doing something different, the reduction in avoidable food waste was 43 percent, a statistically significant change (WRAP, 2013).*

Netherlands: FoodBattle - This initiative focused on tackling food waste in households. Recognizing that information on its own is not enough, the concept encourages people to actually experience the amount of food that is thrown away at home. This involved keeping a diary on how much food is wasted over a three-week period, which is combined with practical tips and specific interventions. The role of social environment (neighbours, societal groups, shopping locations, etc.) is a specific aspect of the FoodBattle intervention. The first FoodBattle in the Netherlands resulted in participating households wasting 20 percent less food in a period of three weeks (Bos-Brouwers, 2013). The second FoodBattle in 2014 together with a national women's organization *Vrouwen van Nu* resulted in a reduction of edible food waste of 30 percent.

Denmark: Stop wasting food - This Danish NGO consumer movement against food waste is set up by consumers for consumers. It seeks to increase public awareness by organizing campaigns, mobilizing media, and encouraging discussion, debate and events of all kinds, all with the aim of decreasing FLW. It is empowering consumers to take action and to take individual initiatives such as cooking leftovers, shopping more wisely and distributing surplus food. It contributes to the Initiative Group Against Food Waste under the Danish Minister for the Environment.

Source: http://www.bbc.co.uk/news/world-asia-china-21711928; [2] http://e-jen.net/html/newpage.html?code=1;http://intl.ce.cn/sjjj/qy/201307/15/t20130715_566223.shtml; http://www.stopspildafmad.dk/inenglish.html

At the regional level, in Europe, the Directorate-General SANCO has compiled up a database of current EU FLW initiatives, at various levels, from individual businesses to multistakeholder initiatives.[30] Among the latter, the "*Every Crumb Counts*" initiative involves on a voluntary basis, businesses in the food supply chain, committing to work towards preventing edible food waste, and a life-cycle approach to reducing FLW. Another major European initiative is the 2012–2016 EU research project *FUSIONS,*[31] bringing together universities, knowledge institutes, consumer organizations and businesses to improve the knowledge base, targeting improvements in FLW monitoring, social innovative measures for optimized food use in the food chain and the development of guidelines for a possible EU-wide FLW policy to support EU FLW reduction objectives.

In 2013, FAO, the United Nations Environment Programme (UNEP) and partners launched the *Think.Eat.Save: reduce your foodprint Campaign*[32] to support the *SAVE FOOD initiative* (see Box 29) in the area of prevention and reduction of food waste. The Campaign is also part of the *FAO-UNEP Sustainable Food Systems Programme*[33] that has emphasized the importance of food loss and waste management and recycling and the need to mobilize all stakeholders in industrialized, emerging and developing countries as part of improving the sustainability of food systems.

Finally, one of the major initiatives at global level is the UN Secretary-General's Zero Hunger Challenge, launched in June 2012 on the occasion of the United Nations *Conference on Sustainable Development*, also known as Rio+20. The challenge includes addressing sustainability of all food systems and the aim of zero food loss and waste. It has been adopted by the 22 multilateral organizations that constitute the High-Level Task Force for Global Food Security (HLTF)[34] as a guide for a coherent systemic approach to food and nutrition security.These multistakeholder initiatives can fit multiple purposes; they have the potential to: raise awareness; initiate a dialogue between diverse stakeholders; be a means to share information and best practices at various levels; contribute to initiate a common understanding on drivers and main causes of FLW; and catalyze interest of actors, in order to initiate a more organized approach to food losses and waste reduction.

One of the challenges is often to transform awareness raising and initial dialogue towards more concrete action. Public authorities (including at international level) can play a lead role in convening this action-oriented dialogue among private actors and other concerned stakeholders.

Box 29 SAVE FOOD, a *Global Initiative on food loss and waste reduction*

At global level, one of the key initiative is the *Global Initiative on food loss and waste reduction* (also called *SAVE FOOD*)*,* launched in 2011 by the FAO and Messe Düsseldorf GmbH. SAVE FOOD, in partnership with donors, bi- and multilateral agencies, financial institutions, public, private sector and civil society, enables and facilitates: (i) awareness raising; (ii) collaboration and coordination of worldwide initiatives, in a global *partnership* of public and private sector organizations and companies that are active in the fight against food loss and waste; (iii) evidence-based policy, strategy and programme development; and (iv) technical support to investment programmes and projects implemented by private and public sectors. This includes technical and managerial support for, as well as, capacity building (training) of food supply chain actors and organizations involved in food loss and waste reduction, either at the food subsector level or policy level. SAVE FOOD is conducting a series of field studies on a national–regional basis, combining a food chain approach to loss assessments with cost–benefit analyses to determine which food loss reduction interventions provide the best returns on investment. Further, the initiative undertakes studies on the socio-economic impacts of food loss and waste, and the political and regulatory framework that affects food loss and waste. Studies have already been conducted in Kenya and Cameroon on will cover several countries on cereals, fruits and vegetables, roots and tubers, milk and fish (FAO, 2014cd).

Source: http://www.fao.org/save-food/savefood/en/; http://www.save-food.org

[30] http://ec.europa.eu/food/food/sustainability/good_practices_en.htm

[31] www.eu-fusions.org

[32] http://www.thinkeatsave.org

[33] http://www.fao.org/ag/ags/sustainable-food-consumption-and-production/en/

[34] http://www.un-foodsecurity.org/structure

Reducing food losses and waste thus requires identifying causes (see Chapter 2) and selecting potential solutions adapted to local and product specificities. It includes evaluating potential costs and benefits of various options for different actors along the chains. The implementation of the selected solutions could require the support or involvement of other actors, inside the food chain or at broader levels. This often calls for coordinated action of multiple stakeholders. It also calls for actions at policy level.

To various extents, for post-harvest losses, the organization of causes to FLW, and especially meso- and macro-levels (Chapter 2), mirrors the individual and collective challenges and constraints to investments and to best practices in agriculture and food chains, and to agricultural development in general. Therefore, very often, finding ways to implement solutions to reduce post-harvest losses invites revisiting, in an often very tangible way, the very large and often abstract questions posed by agricultural development in general.

A similar rapprochement between FLW and broader sustainable development issues can be made for losses in retail and consumer waste: constraints to FLW reductions are often the very same constraints to improvements in resource-efficiency and sustainability of distribution and consumption systems. Therefore, solutions leading to FLW reductions are to be seen in the context of sustainable food systems, and as part of actions leading to more sustainable food systems.

We propose in the following chapter a way to approach the design of appropriate, situation specific strategies to reduce FLW, for more sustainable food system, and for food security and better nutrition.

4 ENABLING THE CHANGE: A WAY FORWARD TO FOOD LOSSES AND WASTE REDUCTION STRATEGIES

This report confirms that reducing food losses and waste is one concrete way to improve the sustainability of food systems, towards food and nutrition security. As such, reducing FLW goes much further than just optimizing the functioning of the food system: it can be part of broader systemic changes towards more sustainable food systems and global food security.

To contribute to this enterprise, the present report clarifies the question of definitions of FLW, including by introducing the notion of food quality losses and waste (FQLW), and it highlights the importance of sound methodologies for data collection, as currently available estimates are often still fragile. The HLPE defines sustainable food systems in relation to food security and nutrition. The report further describes the impacts of FLW on food systems and food security in its various dimensions (Chapter 1). "Reducing FLW" can be a simple message, speaking to many actors in the food system, to understand SFS and FSN, and to address them with actionable levers.

There are many causes to FLW. The report shows that for a diagnosis leading to solutions, it is crucial to identify causal links to FLW, as well as constraints to implement solutions. To enable this exercise, one of the report's main innovations is to propose a "hierarchy" of causes to FLW (Chapter 2), which is important to guide action and understand the different levels of solutions (Chapter 3).

There are proven solutions, at different levels, to reduce FLW and the report presents some of them. The report shows that solutions need to take into account that there are different levels of causes, and that the causal links have to be considered and addressed. This calls often for coordinated action. This is why the report proposes three levels of solutions. However it is not so simple to implement them.

Context-specific causes of FLW means that solutions to reduce FLW are also very context-specific. The specificities of the food systems, local conditions of agriculture, fisheries, and animal husbandry, infrastructure, transport and retail, as well as "cultural" habits and modes of consumption make any package of solutions very much context-dependent. There is no one-size-fits-all package to fight food losses and waste.

Deciding what strategy to adopt, at individual and collective level, adapted to specific contexts, which can be very diverse between countries, necessitates a thorough analysis of causes and the consideration of winners and losers, and of costs and benefits for all involved. It also necessitates the promotion of individual and collective action of many actors along the food chain, and in support of them.

Addressing FLW goes with a stronger emphasis on the value of food and on the need to preserve it. It goes with changes towards more efficiency and sustainability, and to reconcile economics with the real value of resource use. Key to it would be to recognize an economic value to food that can still have a use in spite of having lost some of the expected qualities, as food, feed or for energy. In addition co-products and food-related waste can also be better valorized.

Based on this, the HLPE proposes here a "way forward" for an impetus at country level, for all actors to build, together, locally-adapted and properly coordinated food losses and waste reduction strategies. This way forward is not prescriptive of the ultimate package of solutions, which will have to be locally adapted, at national level, but also at the level of a sector, or of a business, or at household and individual level. Rather, what is recommended here is a method for enabling change.

4.1 A way forward to reduce FLW in different contexts

The proposed way forward accounts for the fact that any solution at actor level to fight food losses and waste will be more effective (if not only) when accompanied by concerted actions among various actors and effective policy changes. Throughout all these steps, three fundamental dimensions of coordination are identified: across governmental departments, multi-actors, and public–private.

The need for concerted action stems from the fact that food losses and waste happen at one stage of the chain often because of the action of other actors (see Chapter 2). Also at micro-level, actor specific technical solutions to reduce FLW, or the improvement of practices, can take place, but often it does so only provided adequate investments are put in place, or provided behaviour change is facilitated.

Figure 8 The way forward to food losses and waste reduction strategies

1 Gather information and data

Agree on scope of FLW definition **(global level)**

Agree on protocols for measure **(all levels)**

Collect data, and promote transparency and corporate social responsibility **(all levels)**

2 Diagnose and develop strategies

Identify hotspots of losses and waste **(all levels)**

Identify the causes at different levels **(all levels, see Appendix 1)**

Identify solutions **(all levels, see Appendix 2)**

Identify costs and benefits for all actors **(all levels)**

Decide on implementation path and plans of action, what to do effectively at actor level and concerted actions at collective level

3 Act, individually and collectively

Raise awareness and support multistakeholder initiatives **(all levels)**

Roll out the actor-level, individual and collective plans of action, for all actors, producers, businesses, and consumers **(see Table 2)**:

- Investments
- Good practices
- Behavioural change
- Coordination inside food chains
- Valorization of food and by-products

Consider systemic evolutions, including drivers of change (economic, social and cultural)

Experiment and learn lessons

4 Coordinate policies to reduce FLW for SFS and FSN

Set an enabling environment

Support capacity building

Integrate food losses and waste concerns, and a food chain approach, in agricultural policies and development programmes

Adapt other policies

Build specific FLW policies

Set FLW reduction targets

One difficulty stems from the fact that the cost of so doing might fall on one actor, while the benefit of the action will fall on another. This calls for means to share costs and benefits along the chain, towards a positive outcome for all, including social, economic and environmental benefits. It also calls for public policies to support or incentivize the action of all actors to fight food losses and waste.

The way forward that the HLPE proposes for enabling change comprises four main stages: (i) information and data; (ii) diagnosis and strategy; (iii) action; and (iv) coordination of policies – see Figure 8. The categorization and hierarchy of causes of food losses and waste shown in Chapter 2 can guide the diagnosis and analysis of food losses and waste in a given context and situation. The review carried out in Chapter 3 of the potential solutions to the different levels of causes can give ground to deciding the most adapted strategies and plans of action whose implementation will involve multiple levels and actors.

No measure is *ex-ante* prescribed. What is proposed is rather a method and areas for actions, to tackle all stages of the food chain where food losses and waste happen, to address all levels of causes, micro-, meso and macro.

The three first stages of this "way forward" are relevant to various levels: these stages can be rolled out as such by one particular sector or actor, business or household; they can be rolled out, in addition, collectively at national level, within a process that will put all food chain actors at the table, fostering coordination among actors, public–private actions and coordination between sectoral policies.

4.2 How to construct the way forward?

This section details how to construct the way forward, including how to use elements of this report, and provides relevant recommendations to all actors.[35]

4.2.1 Improve data collection and knowledge sharing on FLW

A definition of FLW is proposed in this report. Addressing FLW starts with a mutual understanding of what it is all about. To do so:

> *All stakeholders should agree on a shared understanding, definition and scope for FLW (1a).*

There is a need to harmonize, across commodities and different stages of the supply chain, the measurement frameworks for FLW, to allow for structural, reliable and comparable data about the amount of FLW within countries but also at global level, to facilitate exchanges of information and experiences. The use of standardized criteria is key to measuring FLW and to assess where to take action to reduce FLW. These criteria must be scientifically supported and validated by stakeholders in order to reconcile the different situations regionally and over time. Different initiatives currently exist and there is a need to harmonize the work on measurements. To support this:

> *FAO could consider developing common protocols and methodologies to measure FLW and analyse their causes. This should be done through an inclusive and participatory process, taking into account product, country and all stakeholders' specificities and building upon FAO's experience (1c).*

This effort should be science-based and inclusive, applying to (and being usable by) all actors in the food system. The work should include a critical look at the reliability of data and methods used for assessment and projections. This approach should also aim to define the conditions for certified procedures.

Collecting reliable data on FLW is key to identify hotspots and priorities of action. Often detailed data are available within the companies, however, with the exception of a limited number of leading retailing and food processing companies, hardly any food chain company is currently transparent about the levels of FLW. Transparency can be encouraged by policy and be organized in collaboration with statistical offices (to harmonize the reporting of data), the private sector (along food chains, traders, etc.), organizations (to be able to collect detailed information about specific commodities and supply

[35] The Summary and Recommendations section of this report provides, for each of the stage of the "way forward", recommendations as directed to different categories of actors: these recommendations are here highlighted in italics and their numbering is shown between parenthesis.

chains) and academics (to guarantee independent and transparent processes). Companies and private sector organizations need to be involved in this process, on the basis of their assessment of the levels of FLW in their operations, using standard transparent methods. Harmonized measurement protocols and easy-to-use manuals dedicated to specific user groups are key in this context. To do so:

> *All stakeholders should improve the collection, transparency and sharing of data, experiences and good practices on FLW at all stages of food chains (1b) and FAO should invite all stakeholders, international organizations, governments, the private sector and civil society to collect and share data on FLW in a coherent and transparent manner at all stages of food chains (1d).*

This could form a global initiative to collect primary data on actual food losses and waste at different levels and different stages through national statistic offices, NGOs, companies, the research community, etc. It should be based on the above pool of harmonized methodological tools and linked to the global strategy to improve agricultural and rural statistics, considering FLW as a key area for data. FAO could host the relevant collected data and make it available to all.

4.2.2 Diagnose and develop effective strategies to reduce FLW

The identification of FLW hotspots and of different levels of causes, of the relevant solutions and how to implement them, should take a multistage approach that includes: (i) micro-level solutions (physical and technical) to be adopted by individual actors; (ii) coordinated solutions to be adopted in a harmonious manner by multiple actors along a supply chain, adopting an interprofessional approach; and (iii) systemic solutions that require action of all, often with necessary support and incentives at the policy level by governments and institutions.

The suitability and effectiveness as well as the urgency of implementing the solutions to reduce FLW should be context-specific, taking into account constraints (including systemic), costs and potential direct and/or indirect impacts. Food losses and waste result from often numerous and interrelated causes including technological limitations, inappropriate practices, poor infrastructure, poor organization, poor linkages among supply chain actors and poor governance. FLW often reveal a lack of relationships inside the food chain/system, lack of communication, lack of valorization/recognition of efforts needed/made at one stage to reduce FLW at another stage (downstream or even upstream).

This calls for improved governance inside food chains, involving all actors (including public and private ones), to organize collective understanding and action, and to appropriately share efforts/benefits of FLW reduction. There is a need to identifying the actors who will be directly implementing solutions, the costs they will be bearing, potential benefits and beneficiaries. It also requires identification of constraints to implementation of the solutions and possible interventions to overcome them. There is also a need to overcome the fact that there is today no large-scale scoping study on the list of existing, adopted measures/investments for FLW reduction, with details on cost–benefit among those measures/investments along the food supply chain for the specific products and actors, and by location in both developed and developing countries.

In this context, in order to pose a proper diagnosis and develop appropriate strategies for FLW reduction:

> *States should convene an inclusive process to identify hotspots, causes of losses and waste at different levels (see Appendix 1 of this report), potential solutions (see Appendix 2) and levels of intervention. This requires identifying the actors who will directly implement solutions, individually or collectively, identifying the costs they will bear, as well as potential benefits and beneficiaries. It also requires identifying constraints (including systemic constraints) and how they would be addressed (infrastructure, technologies, changes of organization in the food chain/system, capacity building, policies and institutions) (2a).*

Based on this:

> *States should determine a plan of action in a manner that includes all stakeholders (2b), and FAO should support these national processes in collaboration with partners to devise methodological guidance adapted to countries' specificities, and needs and priorities of various actors (2c).*

4.2.3 Take effective steps to reduce FLW

Each actor individually, and each actor collectively with others, needs to take actions to reduce FLW.

The States have a key role in enabling FLW reduction actions. In particular, especially in developing countries all actors need to be able to invest in integrated post-harvest management infrastructure, and the private sector will need support, including to allow products to meet phytosanitary, veterinary and food safety standards for trade and export. This includes support to institutions and public infrastructure on logistics, extension services, education for professionals at multiple levels – including train-the-trainer approaches, customs and phytosanitary control, food safety authorities, research and development infrastructures, etc. Strengthening research and development in post-harvest systems is key. A collaborative approach among governments, the private sector, funding organizations, civil society organizations and knowledge institutions is needed. Often practical solutions for post-harvest loss reduction can come from knowledge transfer and lateral spread of good practices, which needs to be thought jointly with the knowledge of local farmers and food chain actors, to ensure that the end result is adapted, acceptable and affordable. To support producers and food chain actors to reduce post-harvest losses, in particular:

> *States should invest in infrastructure and public goods to reduce FLW and to ensure sustainable food systems such as storage and processing facilities, reliable energy supply, transport, appropriate technologies, improved access and connection of food producers and consumers to markets (3a). States should take measures to support smallholders to reduce the FLW by organizing themselves in ways that yield economies of scale and allow them to move towards high-value activities in the food supply chain (3c). States and other stakeholders, including international organizations, the private sector and civil society, should invest in research and development to minimize FLW (3l), and especially design adequate research and extension services, including towards small transport, transformation and distribution enterprises (4e). National and international research and development organizations should increase investment in technological innovations at post-harvest and consumption stages for effective reduction of FLW as well as for adding value to agricultural products in the whole food value chain, for example through the extension of shelf life while protecting nutritional value (3r).*

FLW occur within the private sector, in the food supply chain, down to consumers. A major responsibility to reduce FLW lies therefore within the private sector organizations. Governments do have a role to play to facilitate and support strategies. They may have a convening or facilitating role in organizing the debate, dialogue towards setting an agenda, focusing not only on food supply chain organizations, but including also suppliers to the sector (e.g. technology suppliers, financial institutions, interventions to reduce barriers). In addition, to support concerted actions by the private sector (from global multinational companies to medium and small enterprises), retailers and consumers towards FLW reduction, a proper enabling environment is key. It includes regulating contractual arrangements along the food chain, organization of markets, and managing instabilities of the food system, including dealing with seasonality aspects (HLPE, 2011). To enable this and concerted actions along the food chain:

> *States should implement an adequate framework including regulation, incentives and facilitation so that the private sector (e.g. wholesaler, retailer, catering and other food services) and consumers take robust measures to tackle unsustainable consumption patterns. This framework should also ensure that the private sector better incorporates negative externalities of their activities such as damage to natural resources. (3b) States should create an enabling environment for the reduction of FLW including by encouraging sustainable patterns of consumption among the population, as well as food and non-food investments promoting food security (3d). States should encourage sector-based audits of FLW (3e) and design and introduce procedures to ensure higher corporate accountability standards for FLW, and monitor reductions in FLW in the food processing and retailing sectors (3g). Finally, States should reform public food procurement policies to reduce and minimize FLW while ensuring food safety (3h).*

As seen in Chapter 3, coordinated and concerted levels of actions are key to reduce FLW. This will not take place without specific enabling measures. Therefore:

> *States and other stakeholders, including international organizations, the private sector and civil society, should carry out training and capacity building to strengthen the coordinated use of appropriate technologies (3h). In line with this, all stakeholders should improve communication, coordination and recognition of efforts needed/made at one stage to reduce FLW at another stage, downstream or upstream (4i).*

Experimental innovations or pilot projects can be key to FLW reduction. They need support. In some cases, States can act as a "launching customer" to change business practices and behaviour (e.g. public procurement, in the criteria for sustainable catering, efficient waste management). States can also create experimental environments, e.g. to temporarily reduce barriers to facilitate implementation of interventions (for example gleaning networks, food hygiene regulations). In line with this:

> *States should promote experimentation and the exchange of good practices regarding FLW (3i).*

Macro or systemic levels of causes (Chapter 2) often call for systemic approaches to reduce FLW. It often starts with the recognition of the diversity of food systems and how they relate to FLW. In this regard:

> *States and other stakeholders, including international organizations, the private sector and civil society, should recognize the plurality of food systems in their diverse contributions to FLW and various potentials to reduce them (3j). They should also enable and support multistakeholder initiatives to improve governance along food chains and organize collective understanding and action to reduce FLW (3k).*

Consumers will have to play a great role in the reduction of FLW. Household waste results from a complex set of drivers and factors such as income level, household size, urbanization, infrastructure, the structure of the food supply chain, food cultures, trust in businesses and institutions (including in food safety regulations), and awareness levels, etc. Reduction of consumer waste will result from more sustainable buying, cooking and eating behaviour. Different type of interventions can support this, such as awareness-raising campaigns, experimental interventions, social community approaches, education of young urban and rural people, and women empowerment. Attempts to restore the true value of food, and to restore consumers' recognition of how food is produced and valued in the supply chain, will also lead to reduced consumer waste, as rural–urban movements such as the Slow Food presidiums can show, or as "pick and pay" self-picking initiatives demonstrate. To enable reduction of consumer waste:

> *States and other stakeholders, including international organizations, the private sector and civil society, should improve the dissemination of accurate information and advice to consumers to minimize FLW (3m), and encourage civic engagement of all actors, including consumers, to act concretely to reduce FLW in particular through public campaigns, education of youth and children (3n).*

The private sector in many cases is the first loser when FLW happen (as in the case of the post-harvest system), but its practices and standards can often indirectly lead to FLW, within the food chain and at consumer level (see Chapter 2). To set the ground for FLW reduction by all actors and to enable finding solutions that can benefit all actors:

> *The private sector should develop and implement corporate responsibility policies to diminish FLW including by collecting and sharing data on FLW and ensuring that the costs and benefits of FLW reduction are appropriately shared (3o). It should get involved with collective actions and initiatives for reducing FLW, including by mobilizing companies to change their practices in order to reduce FLW in households (3p). Finally, the private sector should reform supermarket and food retailer practices such as product standards used to accept or reject farmers produce (e.g. size and shape of foods as well as cosmetic standards for fruit, vegetables, livestock products). This can be done, for example, by introducing differentiated pricing to prevent economic and nutrition value losses (3q).*

4.2.4 Improve coordination of policies and strategies in order to reduce FLW

Different sets of policies impact FLW (Chapter 2) covering food and agriculture, development, industry and businesses regulations, food safety, bioenergy, waste policies, research and education, social affairs, sustainable consumption and production, health and dietary guidelines, etc. Therefore an important part of the solutions to reduce FLW can be found in other policies (Chapter 3). For example, addressing food waste at consumer level calls for a variety of approaches, and links to a wide set of policies, from food safety and sustainable consumption policies, organization of the relationship with business, and waste valorization policies. At global level, the Codex Alimentarius Commission has started considering taking on the challenge of possibly revisiting its regulatory orientations in light of their impacts on FLW. At national level, FLW reduction strategies will need coordination among various sectors and sectoral policies, including those managed by different ministerial departments. In agricultural and food policies (such as for instance those covering capacity building, training, extension, food safety management, development projects, etc.) there is often a lack of consideration of an integrated food chain approach. To build FLW reduction strategies and to overcome currently limited consideration of FLW in food, agricultural and other policies:

> *States should ensure a holistic food chain approach (4e) and integrate FLW concerns and solutions, and a food chain approach, in agricultural and food policies and development programmes, as well as in other policies, which could impact FLW (4a). They should strengthen the coherence of policies across sectors and objectives, e.g. sustainable food consumption, dietary guidelines, food safety, energy, and waste (4b). Finally they should support efforts for coherence, clarification and harmonization of the meaning and use of food dates labelling, at national as well as international level, taking into account the principles of the Codex Alimentarius (4d).*

There are potentially many uses for agricultural produce and food (Section 3.2.10). The food-use-not-waste hierarchy (Section 3.3.2) serves as a general orientation.

In line with this, to minimize FLW, optimize the use of resources, and guide policy harmonization efforts to reduce FLW:

> *States should introduce enabling economic policies and incentives to reduce FLW, through a "food use-not-waste" hierarchy, i.e. prevent, reallocate food for feed, recycle for energy through anaerobic digestion, recover for compost, disposal, and ultimately, if no other solution is available, place in landfills (4c).*

Setting aspirational targets to reduce FLW, as in the UN Secretary-General's Zero Hunger Challenge, which contains zero FLW and 100 percent sustainable food system objectives, can be an effective means to increase the level of actions, the sense of urgency and related commitments (including incentive and penalty procedures). Target setting also leads to awareness raising, and therefore:

> *States should set targets of FLW reduction (4c).*

Shared learning, and sharing of experiences, is key to FLW reduction. Campaigning also has a positive impact on changing consumer awareness and attitude towards the issue of FLW. Social innovation approaches, many started bottom-up and as grassroot initiatives, could potentially have positive effects on attitudes. Also sector-level corporate associations/organizations have set up initiatives to exchange information among members. There is currently a growing number of multistakeholder initiatives at global, continental, national, sectorial or regional level to reduce FLW, with different approaches (see Chapter 3). There is a continuous need for: (i) a dialogue between them; (ii) coordination; and (iii) identification of synergies and leverage actions points, etc. To support this, and to enable collective solutions, better coordination and cooperation among all actors, including raising awareness, changing attitudes and behaviour for food consumption:

> *States should support coordination of efforts through multistakeholder initiatives, such as the global "SAVE FOOD" initiative (4f).*

FLW reduction is country and context specific, and there is a considerable added value at global level to share common methods, to learn from other contexts and to share experiences. For instance, developing countries could learn from other developing countries on how to reduce post-harvest losses. Also, with respect to consumer waste, there is a concern to prevent the rise of food waste in countries in transition towards more western life styles. Both developed countries and countries in transition can learn from each other, towards a global level repository of analysis and solutions. To enable sharing methods, learning from other contexts and sharing experiences:

> *The CFS should raise awareness of the importance of reducing FLW and disseminate this HLPE report to international organizations and bodies (4j). It should develop guidelines to assist governments in an assessment of their food systems with a view to reduce FLW (4i) and consider convening an inclusive meeting to share successful experiences, challenges faced and lessons learned from FLW initiatives (4h).*

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APPENDICES

A1 Causes of FLW by stages in the food chain

Identification of causes of FLW is primordial for the identification of solutions to reduce FLW, and priorities for action. FLW can result from a very wide range of antecedents, ranging from biological, microbial, chemical, biochemical, mechanical, physical, physiological, technological, logistical, organizational, to psychological and behavioural causes – including those induced by marketing, etc. Identifying the causes of FLW requires an integrated perspective along the food chain. Hereunder are listed some frequent causes of FLW, organized by stages in the food chain.

Pre-harvest[36]

- External drivers (floods, drought, extended rains, pests).
- Choice of varieties for location and target market).
- Poor agronomic and cultural practices (water/nutrient/pest management, pruning, staking/propping, etc.). General lack of information on good production, harvest and post-harvest handling practices due to poor agricultural extension services, especially for smallholders.
- Poor market access.
- Poor organization among farmers into groups/cooperatives/associations to access services and facilities; and to pool their produce for better market access or to meet contractual obligations.

Harvest and initial handling stage

- Premature or delayed harvesting; due to poverty, fear of theft, lack of information on maturity indices, labor shortages.
- Poor harvesting techniques leading to spillage, mechanical injuries, heat injury.
- Improper drying of grains resulting in fungal infection during storage.
- Poor choice of containers, packaging materials appropriate for the harvested commodities.
- Poor implementation of sanitation and hygiene standards especially for containers used to pack and transport the produce.
- Improper use of agro-chemicals such as post-harvest treatments leading to damage to the produce or unsafe residues; lack of enforcement of existing laws/regulations on safe use of agro-chemicals.
- Lack of knowledge and capacity on good post-harvest handling practices and applicable technologies among the value chain actors (growers, traders, transporters).
- Lack of access to processing facilities in the production areas forcing the farmers to transport their produce to distant processors.
- Lack of schemes that promote or facilitate utilization of unmarketable foods e.g. donation, cottage processing industries in production areas, farmers markets.
- Poor infrastructure for roads, energy and markets.

Storage

- Lack of proper storage facilities for shelf-stable foods such as grains resulting in losses from pest damage, fungal infection including aflatoxin contamination.
- Lack of cold storage facilities for highly perishable commodities such as fruits, vegetables, fish, meat, dairy products.
- Failure to use post-harvest treatments/pesticides/dressing that would prevent against damage from storage pests (lack of information).
- Poor storage conditions; poor ventilation, poor sanitation, gas composition, lighting.
- Mixing different produce which favours deterioration and/or contamination. Lack of curing for root and tuber crops.

[36] Losses of (potential) produce at pre-harvest do not enter into the scope of definition of FLW (see Chapter 1). However pre-harvest conditions or operations can also indirectly (meso effect) lead to FLW at harvest or at a later stages in the food chain (see Chapter 2), and are therefore mentioned here.

- Poor storage conditions for root and tuber crops leading to greening and sprouting.
- Failure to use applicable post-harvest technologies that slow down deteriorative processes during storage.

Processing

- Errors during processing resulting in defects (chain).
- Trimming to achieve desired shape and size.
- Contamination along the processing line.
- Lack of processing facilities; lack of capacity for existing processing units, especially for seasonal commodities.
- Lack of packaging.

Distribution and transport

- Rough handling of produce during packing and loading/off-loading to transport trucks.
- Use of inappropriate containers/packages such as sacks, polythene bags during transport.
- Poor ventilation during transport.
- Poor transport infrastructure; roads, refrigerated trucks.
- Delays at the off-loading docks where no cooling facilities are provided.
- Delays at port of entry for imported products due to inspection for phytosanitary, veterinary or food safety regulations compliance.
- Non compliance to phytosanitary, veterinary or food safety regulations.

Retail outlets

- Pressure to stock/display “perfect” and fresh products.
- Injudicious use of regulated chemicals to maintain fresh appearance leading to unsafe residue levels.
- Use of unregulated chemicals, e.g. calcium carbide for ripening.
- Wasteful displays: large piles, mixed produce (at different ripening stages).
- Regular replenishing of stocks, leading consumers to select most recent products.
- Management of ready/processed food by retailers.
- Inadequate packaging.
- Large pack sizes which force some consumers to buy what they may not use.
- Marketing strategies, product promotions and bulk discounts that lure consumers to buy produce they may not use such as “2 for 1”, or “buy 1 get 1 free”.
- Stock management inefficiencies, overproduction, product and packaging damage (farmers and food manufacturing).
- Inability to predict the demand, difficulty to anticipate the number of clients (catering).
- Lack of alternative markets for products that do not display a perfect aspect or are close to “consume by” dates.
- Lack of donation possibilities.

Consumption

- Attitudes.
- Lack of awareness.
- Lack of shopping planning.
- Confusion about "best-before" and " use-by" date labels.
- Lack of knowledge on how to cook with leftovers (households).
- Inadequate storage.

A2 Solutions at different stages of the food chain

The identification of causes, and of links between micro, meso and macro causes (see Chapter 2) enables the design of pathways for all stakeholders to identify and implement solutions to reduce FLW adapted to the specific conditions and context. We list hereunder an array of such potential solutions, distinguished in three broad categories: (i) those that can be implemented by a single actor (micro solutions), often technical by nature; (ii) those that require a collective action, either of actors at the same stage, or along the food chain; and (iii) those that require collective action at a broader level (national or subnational), generally with the involvement of public authorities.

I) Solutions that can be implemented by individual actors (micro level)

Harvest / Production stage

- Choice of right varieties for location (to achieve best quality) and target market (to mature when there is demand in the market).
- Disease and stress-resistant varieties of crops.
- Proper agronomic and cultural practices to ensure high quality products – reduce losses from culls.
- Proper harvest timing and scheduling for target markets.
- Proper sorting/grading after harvest; with separation based on size, injury and diseased/pest-infestation, different ripeness for fruits to facilitate packaging for delivery to different markets or for different uses.
- Improve storage facilities for perishables at the farm level.
- Use of clean and appropriate containers for the commodities.

Post-harvest handling and storage stage

- Slow down post-harvest deterioration by managing contributing factors (temperature abuse, ethylene, microbial load, solanization, sprouting, contaminants).
- Adapt applicable low-cost post-harvest technologies to local conditions and promote their use among chain actors.
- Promote innovative storage options such as warehouse receipting systems (WRS).

Processing and packaging

- Promote and support cottage industries in production locations to reduce the cost of transport and losses incurred in long-distance transport to far off processors.
- Encourage and support fabrication of locally suited processing units.
- Re-engineer manufacturing processes to ensure efficient use of resources.
- Improve packaging to increase shelf life.
- Better inventory management, waste audits and measurements.
- Packaging, labeling and types of packs as per buyer's requirements, consumer needs of importing countries.
- Development of cheap reusable and/or degradable packaging for developing countries.
- Development of adapted packaging facilities in developing countries.

Transport, distribution and market

- Logistics of refrigerated cargo for shipping to overseas markets.
- Develop good storage facilities in wholesale/retail markets and supermarkets.
- Promote proper organization and display of produce in the retail outlets (avoid mixing and piling of produce, temperature abuse by mixing produce with different temperature requirements in one common cold room etc).
- Change in-store promotions that encourage impulse/wasteful purchases.
- Improve in-store inventory, better inventory management, waste audits and measurements.

Retailing

- Promote seasonal consumption.
- Reduce portion sizes.
- Food service organizations such as hotels, restaurants, catering establishments to relook at serving sizes as per customer/consumer demand and requirements adhering to food safety norms.
- Use of differentiated pricing for products arriving near the use-by date or when food products have lost quality (be it freshness, shape, colour, consistency, taste), in order to avoid them being lost.
- Distribution of excess food to charitable groups.

Consumption

- Improve meal planning.
- Consume before buying.
- Buy only what is going to be consumed.
- Implement good storage practices.
- Correctly interpret 'sell-by, best before' dates.
- Effective use of leftovers and food products after "best before" dates.

II) Concerted and collective actions to reduce FLW (meso level)

Preharvest[37]/Production stage

- Strengthening (including through capacity building) primary producer organizations/Farmers Associations in Good Agricultural Practices, Good Harvest Practices, Good Storage Practices, Good Manufacturing Practices and food loss prevention etc.
- Improve availability of agricultural extension services for small holder farmers to disseminate information needed for good production and post-harvest handling.
- Good harvest practices; training farmers on proper maturity indices and their importance to nutritional and economic value.
- Diversification to hedge against poverty which sometimes forces the farmer to harvest their produce prematurely.
- Horizontal integration (farmer organizations/cooperatives) which can receive credit/advance payment on their produce rather than harvest prematurely due to poverty. Organization of small farmers for up-scaling of their production and marketing.
- Improve linkages (vertical and horizontal integration) among value chain actors to improve efficiency; reduce risk of overproduction by farmers to hedge against failure to meet contractual volumes.
- Facilitate utilization of unmarketable foods, e.g. donation, cottage processing industries in production areas.

Handling and storage stage

- Improve access to low-cost handling and storage technologies (e.g. evaporative coolers, storage bags, metallic silos, crates).
- Train growers, traders, transporters on good post-harvest handling practices and technologies.
- Train actors all along the food chain on good storage practices such as ethylene and microbial management.
- Ensure pest control protocols are followed along the food value chain.
- Public–private partnerships to improve storage facilities (including cold rooms, silos, warehouses) and transportation facilities such as refrigerated trucks for perishables.

[37] Actions at pre-harvest stages can indirectly (meso effect) lead to FLW reduction at harvest or at a later stage in the food chain (see Chapter 2) and can therefore be part of FLW reduction strategies.

- Promote joint/group storage facilities for small-holder farmers who cannot afford the facilities as individuals.
- Enforce good practices on safe use of agro-chemicals.
- Train supply chain operators and raise awareness of all actors on food safety practices, proper use of post-harvest treatments and general hygienic practices to ensure consumer protection and minimize losses from discarding unsafe foods.

Processing and packaging

- Develop and/or strengthen linkages between farmers and processors e.g. through contracts.
- Improve the supply/demand balance for processing facilities, including through alternative uses to avoid losses of seasonal products by lack of transforming capacities.
- Create an enabling environment for processors to encourage more private sector investment in processing.
- Improve supply chain management.
- Develop and/or ensure processors adherence to set standards of processed foods to ensure high quality and safe foods for the consumers and reduce FLW due to sub-standard products.

Transport, distribution and markets

- Facilitate linkages between producers and markets.
- Promote commodity associations/organizations/cooperatives to improve market access and efficiency of their operations.
- Clarify food date labeling practices to avoid misunderstanding by consumers.
- Provide guidance on food storage and preparation to consumers.
- Develop markets for substandard products.
- Facilitate increased donation of unsold foods.

Consumption

- Conduct consumer education on meal planning, good storage practices, food preparation, reuse of leftovers in recipes, proper interpretation of "sell-by, best before" dates.
- Advertisement–corporate messages about food waste prevention , recycling of waste and packaging materials.
- Educate consumers to better plan their buying, buy only after having consumed, and according to planned meals.
- Fight against the practices and messages that devalorize food: 3 for the value of 2, free item added to a menu.
- Food consumers in urban areas to relook their buying habits of foods and food products.

Cross-cutting measures

- Develop capacity of all supply chain actors to identify critical control points for FLW reduction.
- Training, building capacity of all supply chain actors in good practices.
- Exploration of alternate uses of food wastes, composting.

Systemic solutions

- Putting all actors together.
- Creation of national/regional food loss prevention platforms in association with farmers organizations, industry associations.
- Identify and monitor critical points for losses in the supply chains of the different products.
- Elaboration at national and/or sector level FLW prevention guidelines and protocols.
- Food chain efficiency.
- Promote production efficiency in food manufacturing units in both unorganized and organized sectors and better turnout of input: output ratio. Promote good inventory management (e.g FIFO,

First In First Out, or FEFO, First Expired, First Out) by the food producers and food processors and other actors in production/ manufacturing activity in the food chain.

- Encourage organization and management innovations for production planning, sorting, grading, logistics.
- Valorize waste or by products at all levels.
- Development of method/systems to valorize food waste and food-related waste, including modifications of systems in place.
- Promotion/encouragement of technological innovations in utilization of by-products in food supply chains for food and non-food uses.
- Promote short chains and local solutions.
- Promote local sourcing of raw materials and local transformation.
- Promote traditional/local technology innovations for prevention of food losses.

III) Enabling the change: solutions at macro or systemic level, towards FLW policies and towards consideration of FLW in other policies

Preharvest[38]/Production stage

- Improve market access; encourage and support formation through farmer groups, cooperatives, associations and link them to markets, encourage contractual farming and long-term contractual agreements between growers and processors.
- Create alternative markets for the rejects/culls, e.g. regular farmer markets/shops close to the consumers.

Handling and storage stage

- Improve infrastructure for roads, energy and markets especially in rural areas where most of the production occurs.

Processing and packaging

- Facilitate local transformation, including by encouraging investment.

Transport, distribution and market

- Develop efficient market systems especially for perishables.

Consumption

- Education on food waste, if possible integrated in a broader perspective on food use and nutrition.
- Ensure home economics taught in schools, colleges and communities to enhance better utilization of food.
- Businesses and institutions such as schools, colleges, educational institutions, hospitals and other business organizations to create awareness on prevention of food waste, food wastage footprint, green concept.

Cross-cutting measures

- Building capacity (human and infrastructural) of institutions in developing countries for research; so as to develop appropriate (local) solutions to reduce postharvest losses.
- Build capacity of extension agents (in post-harvest handling) and facilitate their access to small holder farmers.
- Professional education and formation in good practices and food safety. Education on food waste, if possible integrated in a broader perspective on food use and nutrition.

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[38] Actions at pre-harvest stages can indirectly (meso effect) lead to FLW reduction at harvest or at a later stage in the food chain (see Chapter 2) and can therefore be part of FLW reduction strategies.

Systemic solutions

- Putting all actors together.
- Raise awareness on the impact of, and solutions for food loss and waste.
- Collaboration and coordination of worldwide initiatives on food loss and waste reduction.
- Policy, strategy and programme development for food loss and waste reduction.
- Support to investment programmes and projects, implemented by private and public sectors involved in food loss and waste reduction.
- Facilitate access to credit for small holders and other actors/stakeholders in the food chain.
- Organize mapping of food value chain/food supply chain in order to have a clear understanding on structure of chains, key players and their roles, products and services, marketing channels etc.
- Global harmonization of measurement protocols, frameworks.
- Organize networks to collect primary measurements and data.
- Quality/standards dimension.
- Develop markets for multi-graded commodities/products.
- Promote adherence of quality standards for perishables such as horticultural crops, meat, fish and poultry.
- Revisit food laws and standards to facilitate prevention and reduction of FLW.
- Food chain efficiency.
- Adopting a food chain perspective in agriculture development projects (where is the produce going to be consumed, how is it going to be transported, transformed, etc.).
- Facilitate adherence to International standards, and food standards of the importing countries, including sanitary and phyto-sanitary measures for export of food items/products.
- Valorize waste or by-products at all levels.
- Selective waste collection.
- Development of cold chain for perishables.
- Building evidence for policy making.
- Support research projects to quantify food loss and wastes to provide a basis for policy making.
- Support cost/benefit analysis for proposed interventions/solutions for FLW reduction.

A3 The HLPE project cycle

The HLPE has been created in 2009 as key element of the reform of the Committee on World Food Security (CFS), which is the foremost inclusive international and intergovernmental platform for a broad range of committed stakeholders to work together in a coordinated manner and in support of country-led processes towards the elimination of hunger and ensuring food security and nutrition for all human beings.[39]

HLPE's key functions are: to assess and analyse the current state of food security and nutrition and its underlying causes; to provide scientific and knowledge-based analysis and advice on specific policy-relevant issues, utilizing existing high quality research, data and technical studies; to identify emerging issues, and help members prioritize future actions and attentions on key focal areas.

The HLPE receives its mandate from CFS and reports to it. It produces its reports, recommendations and advice independently from governmental positions, in order to inform and nourish the debate with comprehensive analysis and advice.

The HLPE has a two-tier structure:

- A Steering Committee composed of 15 internationally recognized experts in a variety of food security and nutrition related fields, appointed by the Bureau of CFS. HLPE Steering Committee members participate in their individual capacities, and not as representatives of their respective governments, institutions or organizations.
- Project Teams acting on a project specific basis, selected and managed by the Steering Committee to analyse/report on specific issues.

To ensure the scientific legitimacy and credibility of the process, as well as its transparency and openness to all forms of knowledge, the HLPE operates with very specific rules, agreed by the CFS.

The project cycle to elaborate the reports, in spite of its being extremely time constrained, includes clearly defined stages. Starting from the political question and request formulated by the CFS, the HLPE organizes a scientific dialogue, policy-oriented. This includes the work of a topic bound and time bound Project Team under the Steering Committee's scientific and methodological guidance and oversight. It includes also external open consultations and an external scientific peer-review on a pre-final draft. The report is finalized and approved by the Steering Committee during a face-to-face meeting (Figure 9).

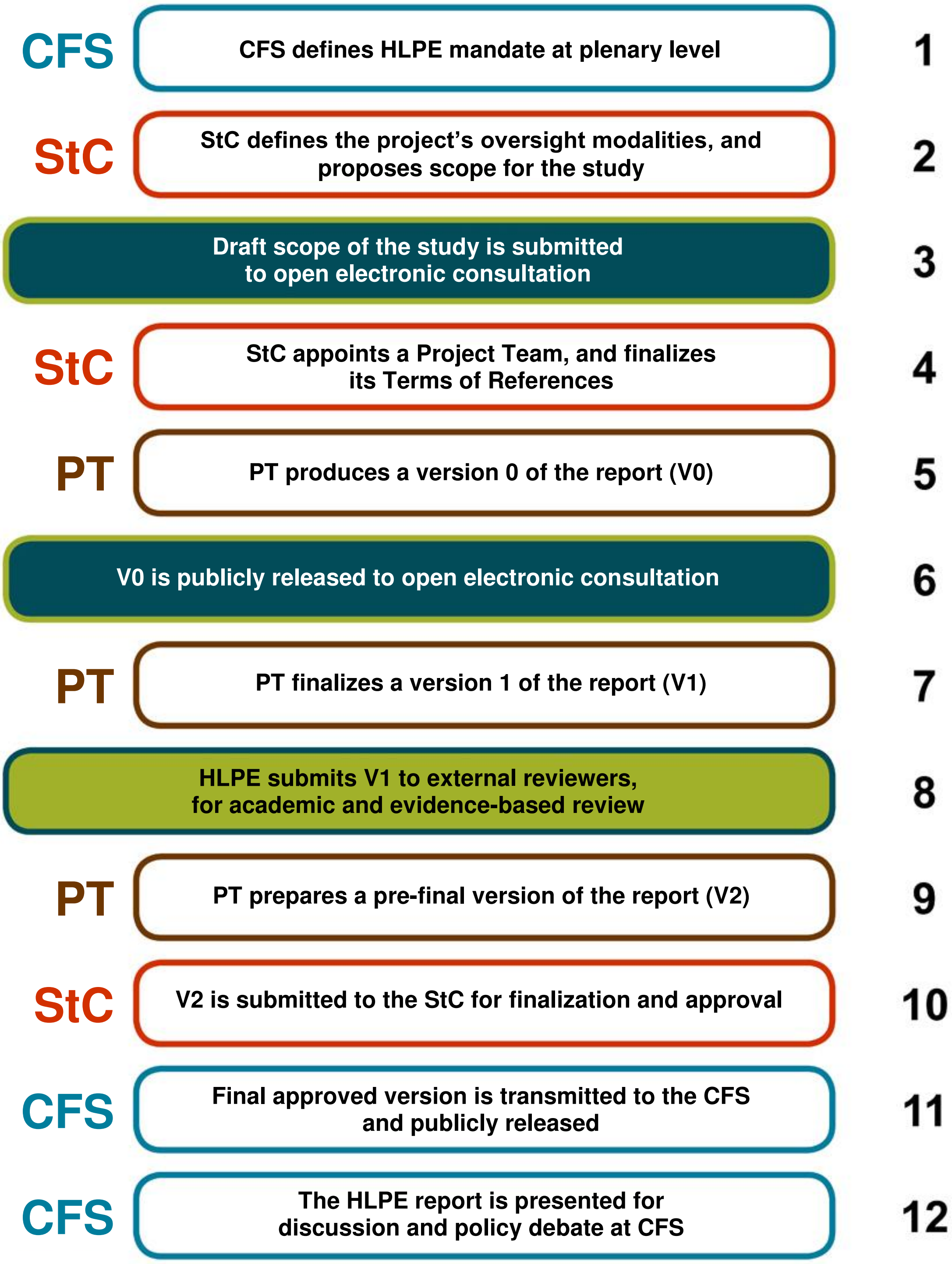
The HLPE runs two open consultations per report: first, on the scope of the study; second, on a V0 "work-in-progress" draft. This opens the process towards the experts HLPE roster (there are currently more than 2000 of them), and all experts interested and as well as to all concerned stakeholders, which are also knowledge-holders. Consultations enable the HLPE to better understand the issues and concerns, and to enrich the knowledge base, including social knowledge, thriving for the integration of diverse scientific perspectives and points of view.

The final approved report is transmitted to the CFS, published and translated in the 5 other official languages of the UN (Arabic, Chinese, French, Russian and Spanish), and serves to inform discussions and debates in CFS.

All information regarding the HLPE, its process and all former reports are available at the HLPE Website: www.fao.org/cfs/cfs-hlpe.

[39] CFS Reform Document, available at www.fao.org/cfs

Figure 9 HLPE project cycle



CFS Committee on World Food Security
HLPE High Level Panel of Experts on Food Security and Nutrition
StC HLPE Steering Committee
PT HLPE Project Team

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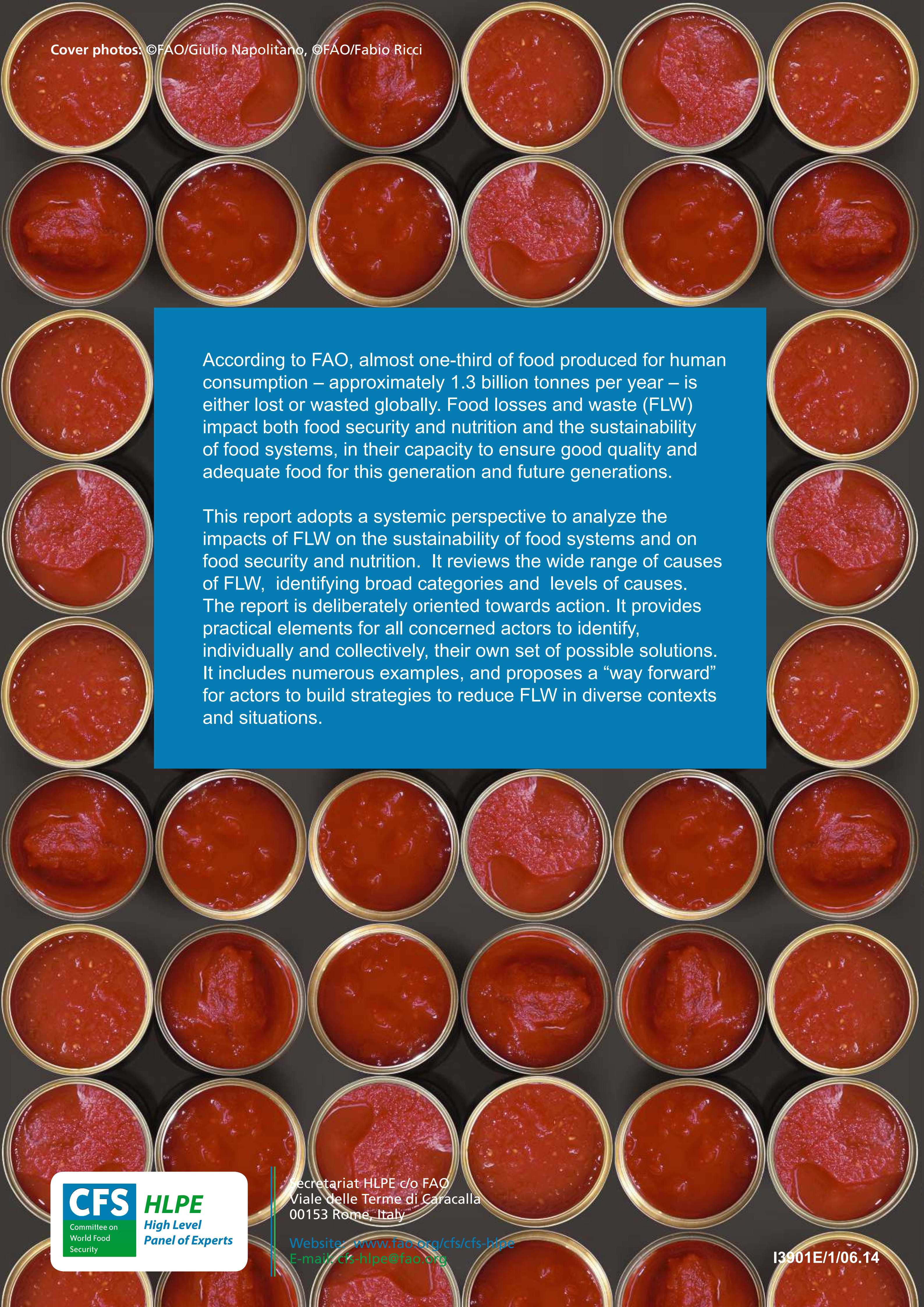

According to FAO, almost one-third of food produced for human consumption – approximately 1.3 billion tonnes per year – is either lost or wasted globally. Food losses and waste (FLW) impact both food security and nutrition and the sustainability of food systems, in their capacity to ensure good quality and adequate food for this generation and future generations.

This report adopts a systemic perspective to analyze the impacts of FLW on the sustainability of food systems and on food security and nutrition. It reviews the wide range of causes of FLW, identifying broad categories and levels of causes. The report is deliberately oriented towards action. It provides practical elements for all concerned actors to identify, individually and collectively, their own set of possible solutions. It includes numerous examples, and proposes a “way forward” for actors to build strategies to reduce FLW in diverse contexts and situations.

CFS Committee on World Food Security

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