Food security impact of global equities

Annex Measurement methodology for *food loss avoided*

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1. Post-harvest food loss avoided

1.1 Agricultural food product groups and supply chain activities

Four commodity groups are defined to evaluate post-harvest food loss
Evaluating the post-harvest food loss situation in a country requires identifying food products or food product groups which should be considered. According to the FAOSTAT's Food Balance Sheets[1] we can define the following four commodity groups:

1. Cereals (excluding beer): wheat, rice (milled), barley, maize, rye, oats, millet, sorghum, other cereals.
2. Roots and Tubers: potatoes, sweet potatoes, cassava, yams, other roots.
3. Oilseeds and Pulses (including nuts): soybeans, groundnuts (shelled), sunflower seeds, rape and mustard seed, cottonseed, coconuts (incl. copra), sesame seed, palm kernels, olives, other oil crops.
4. Fruit and Vegetables (including bananas): oranges and mandarins, lemons and limes, grapefruit, other citrus, bananas, plantains, apples (excl. cider), pineapples, dates, grapes (excl. wine), other fruit, tomatoes, onions, other vegetables.

Focus on vegetables and fruits as key sources of food loss
FAO research (FAO, 2013) shows that most food loss occurs in the following product groups: vegetables, meat, and fruits. Because meat is outside the scope of this research assignment, the relevant food group to focus on is Fruits and Vegetables.

Focus on post-harvest handling and storage
Within the post-harvest food supply chain, i.e. the food trajectory from farm to retailer, we can distinguish three 'main types' or clusters of post-harvest activities: post-harvest handling and storage, processing and distribution/transportation. Figure 1.1 (FAO, 2011) shows for the product group fruits and vegetables the food loss through the different supply-chain stages. In this study the focus is set on post-harvest handling and storage.

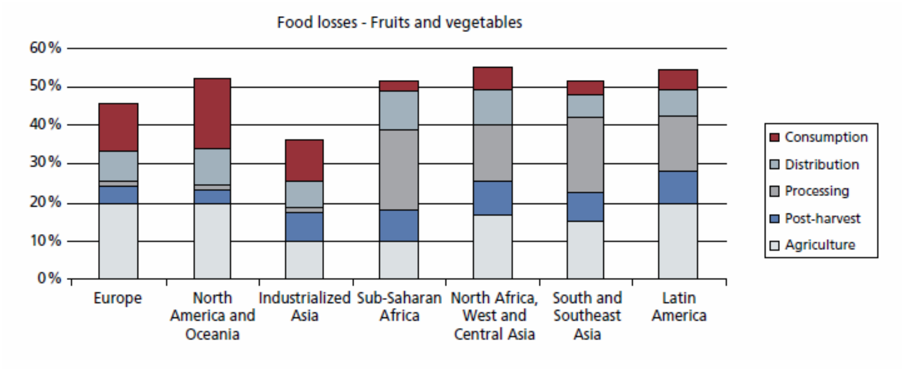

Figure 1.1 Part of the initial production lost or wasted at different stages of the FSC for fruits and vegetables in different regions (FAO, 2011)

[1] http://www.fao.org/corp/statistics/en/

1.2 Identifying key agricultural technologies

Linking technologies to food loss using a three-step approach

Before identifying the key agricultural technologies related to post-harvest food loss for fruits and vegetables, we define the concept 'technology' as used in this project. The following working definition is formulated: '*A technology is an existing physical system that is used directly for preventing loss of a perishable product in the post-harvest phase*'. To determine the technology linked to the causes of food loss we take a three-step approach (see Table 1.1):

1. Clustering the main types of post-harvest food loss for fruits and vegetables; The main types of post-harvest food for fruits and vegetables loss are[2]:
   i. Mechanical damage / physical damage;
   ii. Physio-biochemical loss / deterioration;
   iii. Microbial spoilage;
   iv. Physical rejection.
2. Relating the main types of food loss to their causes (primary and secondary);
3. Determining key clusters of technologies related to these causes.

Table 1.1 From types and causes of food loss to technology

Types	Primary cause	Secondary cause	Main Technology
Mechanical damage / physical damage	Damage, bruising, cracking. Rotting due to fungal and bacterial pathogens is often indicative of physical damage	'Wrong' use or absence of packaging and high temperature and relative humidity during harvest, storage and transport favour the development of post-harvest decay organisms.	Packaging Cold storage / climate control
Physio-biochemical loss / deterioration	Senescence or aging process (unavoidable): Transpiration, respiration, sprouting	Packaging can reduce the aging process by providing ventilation to prevent dehydration, temperature rises, etc.	Packaging
Microbial spoilage or loss	Rotting caused by fungi, bacteria, yeast and moulds	High temperature and relative humidity during harvest, storage and transport favour the development of post-harvest decay organisms.	Cold storage / climate control Cold transportation
Physical rejection or loss	Injury in relation to 'wrong' or absence of refrigerated storage, temperature and relative humidity, composition and proportion of gases in controlled atmosphere storage, type of wrapper or packaging		Packaging Cold storage / climate control

2 https://postharvest.nri.org/scenarios/fruit-and-vegetables.
http://www.agriinfo.in/default.aspx?page=topic&superid=2&topicid=2046.
http://www.fao.org/docrep/T0073E/T0073E01.htm#Foreword

Focus on cold storage and packaging as key technologies to reduce food waste in fruits and vegetables

It is generally accepted that perishable crops, like fruits and vegetables, should be kept cool to delay the onset of deterioration as long as possible[3]. As shown in the Table 1, deterioration is often indicative of physical damage. The table also shows that packaging, temperature control and climate control (i.e. controlling mainly relative humidity) are the main technologies leading to less food loss because of mechanical damage / physical damage, physio-biochemical loss / deterioration, microbial spoilage and physical rejection. Because temperature affects relative humidity (the colder the temperature the less moisture the air can hold) temperature or cooling is one of the most relevant ways to control this. The focus technologies in this study are thus cold storage and packaging.

Cluster 1: Cold Storage - Cold handling and storage systems reduce food loss of perishable products. Cold handling and storage systems as an investment to prevent perishable food losses is widely used in developed countries (Kitinoja, L., 2013), but far less developing countries (see Table 1.2). Cooling provides the following benefits for perishable horticultural foods:

- Reduces respiration: lessens perishability
- Reduces transpiration: lessens water loss, less shrivelling
- Reduces ethylene production: slows ripening
- Increases resistance to ethylene action
- Decreases activity of micro-organisms
- Reduces browning and loss of texture, flavour and nutrients
- Delays ripening and natural senescence

Table 1.2 The Cold Chain, Food Security and Economic Development

Variable	Global	Developed countries	Developing countries
Refrigerated storage capacity (m^3/1,000 inhabitants)	52	200	19
Food losses (all products)	25%	10%	28%
Losses of fruits and vegetables	35%	15%	40%
Losses of perishable foodstuffs due to lack of refrigeration	20%	9%	23%

Source: IIR. 2009. The role of refrigeration in worldwide nutrition (www.iifiir.org)

Focus on cold storage as key factor of loss during post-harvest storage

Four main types of cooling exits including pre-cooling; cold storage; processing-chilling or freezing; and refrigerated transport. As Figure 1.1 (page 5) shows, food loss in developing countries arises primarily in the post-harvest handling, (including storage) and the processing stages. The latter refers to losses related to e.g. juicing and canning, and here cooling is less an issue. For storage, as part of the post-harvest handling stage in the supply chain, cooling is significant. In the context of this research we therefore focus on cold storage. Cold storage refers to the storing of goods in a refrigerated atmosphere. This means heat is removed from the storage container or room to prevent spoilage of foods. The two most important requirements of cold-storage are 1) machinery to remove the heat and maintain the required temperature in the storage unit, and 2) isolation of the storage unit.

Cluster 2: Packaging - Packaging plays a vital role in protecting food and thereby preventing food loss. Packaging plays a vital role in protecting food in the supply chain. Functions of packaging include (Verghese et al., 2012):

- protection, including preventing breakage, spoilage and contamination;
- promotion, including describing product features, ingredients and branding;
- information, including product identification, product preparation and end-of-life management;
- convenience, including preparation and portioning;
- utilisation and handling, including providing for transport and retailing; and
- waste reduction, including increasing shelf-life.

[3] https://postharvest.nri.org/

Focus on secondary/tertiary packaging between farm gate and retail
A combination of different materials and packaging formats is used to address the increasing consumer demand for fresh and processed foods all year round. Packaging can be divided into the following types (Verghese et al., 2015): Primary packaging refers to the retail or consumer pack that contains the sales unit (e.g. a plastic bag, glass jar or steel can, or a plastic crate for loose fresh produce). Secondary/tertiary packaging refers to additional layers to protect and contain the primary packs during distribution (e.g. a corrugated box, plastic or timber pallet, plastic crate for processed foods or stretch wrap). This research focuses on food loss and therefore on the part of the supply chain between farm-gate and retail, and therefore only on secondary/tertiary packaging.

1.3 Impact logic

Agro-companies influence food availability by producing agricultural technologies including cold storage and packaging
Agro-companies produce agricultural technologies which contribute to reducing food loss. The logic that connects these agricultural technologies, such as cold storage and packaging, to food loss reduction / avoided is illustrated in Figure 1.2.

The key output is delivery of improved technologies related to storage and packaging
In the framework of the output-outcome-impact proposed by Vörösmarty et al. (2018), we propose that solutions (technology/product/practice) used by a company are the inputs used for producing the final food product (output).

The key outcome is food loss avoided by using improved technologies
Avoided food loss is the outcome of a certain technology that can prevent food loss (by a certain amount or percentage). Different circumstances (products, supply chains, regions) affect the outcome, resulting in different percentages of food loss avoided.

The key impact relates to food security, in particular food availability/production
Defining impact is not easy. While one can argue that food loss impacts multiple dimensions of Food Security (availability, access, use, stability), the only element this framework allows us to measure is availability. We could accordingly define impact as the contribution of the company towards decreasing global food loss (and therefore increasing food availability). Measuring impact according to this definition should consider the food loss situation in the countries of the company's operation, as well as the market-share of the company in those countries. While the availability of more food due to avoided food loss suggests greater food security, we check whether this link can be made in a rational way for our case-studies. Figure 1.2 shows the rationale of this technology-driven approach to connect 'causes of food losses' to the company's impact.

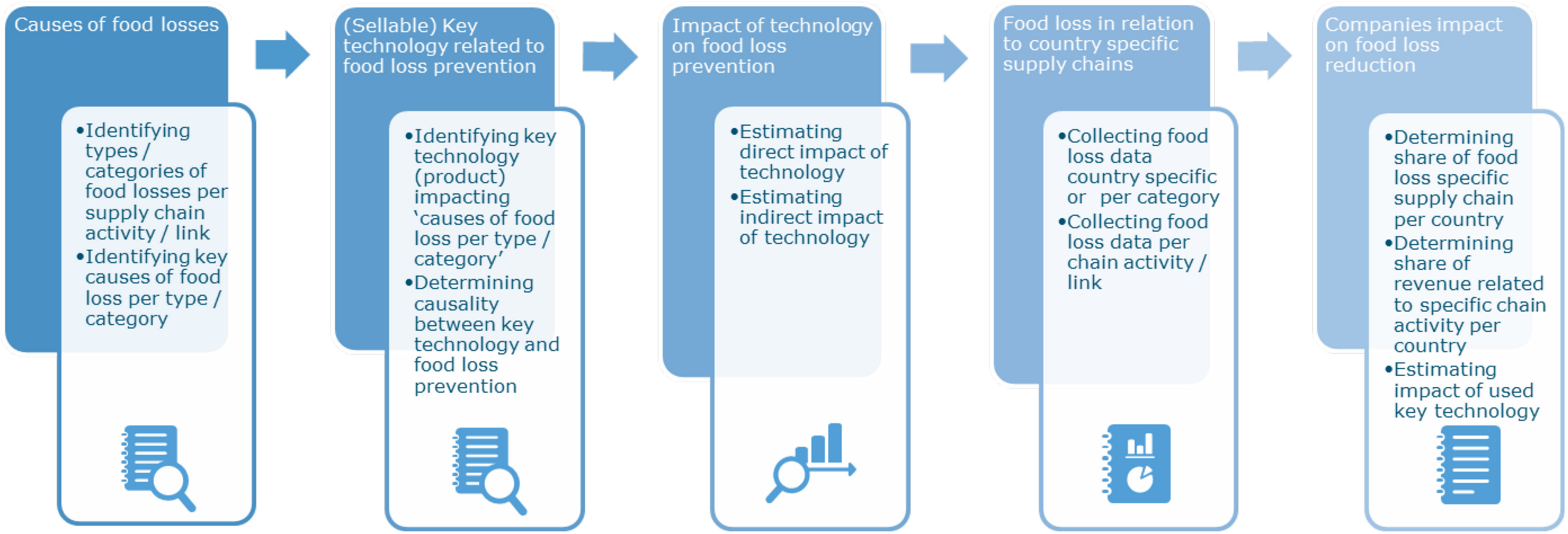

Figure 1.2 Impact logic: from causes of food losses to impact via technology

1.4 Methodology development: to establish the relationship between inputs and food loss avoided

1.4.1 Methodology: Baseline

The counterfactual of delivering improved cold storage and packaging technologies is not 'zero technology', but a lower level of technology available/applied

To measure the impact of a technology, a baseline is needed. For food loss, constructing the 0-baseline is impossible[4]. Food loss is a relatively new research topic and data and insights gathered are quite recent. The most widely accepted and applied data come from the FAO. The FAO food loss numbers implicitly include the current state of technology and its impacts. Most countries and regions use some technology, which means that we cannot simply assume a 'zero baseline'. The total absence of cooling technology has a different effect in different countries and cannot be generalised across all countries, as it depend on many other factors (e.g. climate conditions). As a consequence, the baseline for food loss always implies a certain availability/development of technology.

[4] In the impact analysis regarding health, water and yields, the effect/outcome of the use of the relevant technologies is compared to the situation without these technologies. The situation without these technologies is called 0-baseline.

From improved technologies to food loss avoided taking into account relevance in a certain country or region

To get from improved technology to food loss avoided it is important to define loss reduction by technology. This requires a clear idea of the specific 'baseline technology' applied in the relevant region/country because this baseline is region- and country-specific. The definition must not only be clear, but also applicable. Therefore, we defined the baseline as the technology that is applied in at least 50% of cases in the supply chain in the specific country or region at the time of comparison. This also means that for some countries or regions the use of technology could be zero in more than 50% of the cases, meaning that for those countries or regions the baseline is zero (i.e. '0-baseline').

1.4.2 The outcome of technology on food loss prevention with respect to fruits and vegetables

Calculating food loss avoided

The basic principle and requirement from the client is to develop a methodology that links a company's revenues or selling numbers of a specific technology to food loss avoided. Based on this idea a new formula is developed that calculates the food loss avoided by selling a specific technology (e.g. cold storage or packaging) within a specific country. The formula can be formulated as:

$$OUTCOME\_Local = FLA_{CRT} = \left(\frac{S_{CRT}}{\frac{Q}{1{,}000} * Z}\right) * (\%FL_{RL} - \%FL_{LT})$$

Where $S_{CRT} = Y_{CTR} \,.\, X_{CR} \,.\, S_C$

$$OUTCOME\_Local = FLA_{CRT} = \left(\frac{Y_{CTR} * X_{CR} * S_C}{\frac{Q}{1{,}000} * Z}\right) * (\%FL_{RL} - \%FL_{LT})$$

Table 1.3 Explanation OUTCOME_local equation

Inputs		Description
S_{CRT}		Annual Sales ($) of technology T by company C in country / region R related to Fruit & Vegetables (F&V)
		$S_{CRT} = Y_{CTR} \,.\, X_{CR} \,.\, S_{CR}$
	Y_{CTR}	Share of sales of technology T by company C in country / region R
	X_{CR}	Shares of fruits & vegetables related sales of technology T by company C in country / region R
	S_C	Total annual sales ($) of company C
Q		Cost per capacity U of technology T for company C
Z		Conversion of U to weight for technology T (1 m^3 = … kg F&V)
$\%FL_{RL}$		Current % of food loss of F&V in country / region R in supply chain stage L (= baseline)
$\%FL_{LT}$		% of food loss of F&V when technology T is applied in country / region R in supply chain stage L

1.4.3 Defining the terms of the equation

1. Select the technology (**T**):
   The contribution of a company towards decreasing food loss on a global scale is based on the specific technology sold by the company. Thus, the methodology starts with the selection of technology, or the two technology clusters (cold-storage, packaging) as defined in section 3.2.1.

   Outcome step 1: Let the specific technology (**T**) be the selected technology/technology cluster.

2. Find companies selling the technology (**C**) in the relevant country/region (**R**):
   Select the company (C) selling T and

   a. Identify the countries/regions (R) where the company is selling this technology. Because most financial data are valid for a full financial year (often also a calendar year) a fixed year should be chosen;
   b. Identify the total annual sales ($) of this company C(call it $\mathbf{S_C}$) for this year.
   c. If the company only sells one technology this is also the sales of the selected technology ($\mathbf{S_{CRT}}$ = Y_{CTR} . X_{CR} . S_C. Where $\mathbf{Y_{CTR}}$ = the share of

sales of technology T by company C in region or country R. And $\mathbf{X_{CR}}$ = shares of fruits and vegetables related sales of technology T by company C in region or country R).

Outcome step 2: specific company (**C**), and sales ($) of the specific technology of this company within the countries they sell this technology [$\mathbf{S_{CRT}}$ for all regions where **C** sells **T**]

3. Identify the stage (**L**) in the supply chain where the technology is (regularly) applied:
Food loss is often related to a specific stage (**L**) in the supply chain. For simplicity we assume that the effect of the applied technology on reducing food loss will also be seen at the same stage in the supply chain. **L** could be harvest, transport, storage etc. And L could also be a single stage or multiple stages. For example, packaging could reduce food loss during transportation (**L** 1) as well while storing (**L** 2) the product.

Outcome step 3: Determination of the stage in the supply chain where the technology sold is applicable (**L**)

4. Determine per country the reduction of food loss attributable to the use of the technology at hand:
The number of repetitions of the following sub-steps depends on the number of countries in which the company has sold the specific technology. The sub-steps are:

a. Find the production of fruits and vegetables (F&V) in tonnes, in country R ($\mathbf{P_R}$)
b. Find the food loss (fruits & vegetables) % specific to the stage in the supply chain (L) and the country at hand (R) as a percentage of its production. This is food loss percentage based on the *standard / 'baseline' technology* ($\mathbf{\%FL_{RL}}$) in use (See paragraph Methodology: Baseline on page 8 for more information related to the 'baseline')
c. Relate the sales of the technology (T) by company C to the volume of F&V that is 'handled' by this technology ($\mathbf{V_{CRT}}$) as follows,
   i. Determine the capacity (= volume / m^3) that the technology can 'handle' based on the sales. This is done by dividing the sales (S_{CRT}) by the cost per unit technology (Q) multiplied by the capacity per unit technology (U) ($\mathbf{U_{CRT}}$ = (S_{CRT}/Q) * U)
   ii. Determining the weight (kg) that the technology can 'handle' by multiplying the capacity of the technology (= volume / m^3) by the weight (kg) factor (**Z**) of F&V (where Z is the conversation of U to weight for T (1 m^3 = ... kg F&V)) ($\mathbf{V_{CRT}}$ = U_{CRT}/Z)

d. Identify the food loss (fruits & vegetables) percentage if this specific technology is applied ($\mathbf{\%FL_{LT}}$). Using the food loss numbers from the *developed countries* where the technology (T) is already applied.
e. Calculate for weight (kg) V_{CRT} what would the regular food loss be when the technology (T) is not applied according to step 4b ($\mathbf{TFL_{RL}}$) = V_{CRT} * $\%FL_{RL}$)
f. Calculate for weight (kg) V_{CRT} of what would the food loss be when technology (T) is applied according to step 4c ($\mathbf{TFL_{CRLT}}$ = V_{CRT} * $\%FL_{LT}$)
g. Calculate outcome of applying the technology = the difference between the 'result of step 4f and the result of step 4e. ($\mathbf{FLA_{CRT}}$ = $\Sigma_L[TFL_{RL}$ - $TFL_{CRLT}]$)` = OUTCOME_local

Outcome step 4: Per country the reduction of food loss by selling the technology to that specific country. (OUTCOME_local = FLA_{CRT} = TFL_{RL} - TFL_{CRLT})

OUTCOME_local can also be formulated as:

$$OUTCOME\_Local = FLA_{CRT} = \left(\frac{S_{CRT}}{\frac{Q}{1{,}000} * Z}\right) * (\%FL_{RL} - \%FL_{LT})$$

Note that the first part of the equation (quotient) is the volume in tonnes that is 'in touch' with the new technology.

Normalising the OUTCOME
To get from OUTCOME to IMPACT an intermediate step may be needed to normalise/standardise and to eliminate the effect of the size of the company. A way to do this is dividing the outcome by the revenue (or sales) of that specific company/technology/region. This will prevent those companies with the

highest sales from always generating the highest outcome[5]. In this way outcome is related to the sales (outcome per dollar):

$$OUTCOME\_local\_\boldsymbol{st} = \frac{OUTCOME\_local}{S_{CRT}} = \frac{FLA_{CRT}}{S_{CRT}}$$

5. Add up everything from the 'outcome step 4' for all countries where the company is selling the specific technology:

   Outcome step 5: Gives the total number of food loss avoided (for fruits and vegetables) for the specific company for the sales of technology T in all the countries they are selling.

Step 4c and 4d are explained in more detail

Step 4c.: Conversion of capacity to weight (m^3 --> kg) (**Z**)
Because data related to food loss, technology, cost, etc. is based in some cases on volume and in other cases on weight, the methodology needs to be able to convert the one into the other. Based on http://www.tis-gdv.de/tis_e/ware/inhalt_gesamt.htm and expertise knowledge, Table 1.4 shows the conversion from weight to volume for the most relevant fruits and vegetables.

Step 4d: technology specific percentage of food loss (%$\mathbf{FL_{LT}}$)
In the methodology we need the percentage of food loss of fruit and vegetables when the specific technology is applied by the company within the predefined stage of the supply chain (= %FL_{LT})
However, the FAO data does not show the current state of technology used in a country. For example, knowing that in the processing stage of the food chain in Kenya 20% of fruits and vegetables are lost does not tell us which combinations of technologies are used (storage, cooling, handling, etc.) that lead to this amount of food loss. Improving only one technology (i.e. refrigeration) does not really support any improvements in food loss reduction. A single technology will usually provide a relative contribution to the food loss reduction. For the methodology the main question is how can we calculate this 'relative effect'?

[5] This step leads to the relative impact of a company. If one is interested in the absolute impact of a company, this step should be skipped.

Table 1.4 Conversion from volume (m^3) to weight (tonne) for Fruits and Vegetables

fruit	palletised cartons (m^3/t)	vegetables	palletised cartons (m^3/t)
pineapple	4	artichokes	2.8
apple	2.75	cucumbers	2
avocado	2.75	carrots	2.2
bananas	3.5	potatoes	1.8
pears	2.5	garlic	2.65
grapefruit	2.5	sweet peppers	6.5
kiwi	2.1	asparagus	1.95
lime	1.5	tomatoes	2.5
mango	2.4	onion	2.5
oranges	2.4	beans	1.7
peaches	3.5	peas	1.6
grapes	3	lentils	1.5
lemons	2.5		
average fruit	***2.72***	***average veg***	***2.48***
total average	***2.604 m^3/tonne***		

We reference an extensive literature review by Gogh et al. (2013) of 130 scientific publications and reports from institutions (governmental and non-governmental) to gain insight into the causes of post-harvest losses in fruit and vegetable supply chains in developing economies. 1.5 summarises the number of references mentioned in the 130 records per cause (main and sub) of post-harvest losses in fruit and vegetable supply chains in developing economies.

Table 1.5 Causes of post-harvest losses in fruit and vegetable supply chains in developing economies (based on van Gogh et al, 2013)

Causes of postharvest losses in fruit and vegetable supply chains in developing economies	# references	
cold chain/transport climate control	65	
unsuitable/unfit transportation vehicles		36
absence of cold chain infrastructure		15
poor or limited cold chain infrastructure		7
pre-cooling		7
Storage facilities	66	
Availability of cold storage facilities		32
Large variation in storage performance / non-adaptive use		28
Occurrence of diseases and product damages / bacterial damage		6
Postharvest product handling	59	
Rough handling of produce		26
Poor handling of produce		25
Inefficient, outdated and low level of technology		8
Packaging	45	
Inadequate packaging in storage and transport		22
Low technology packaging		15
Inappropriate use of packaging		8
Infrastructure & connectivity	20	
Poor road quality		7
Little investment in infrastructure		13
Market information/product pricing	26	
General lack of market information		18
Peak season – low pricing		8
Education / R&D	20	
Limited or no education / skills of personnel working in postharvest chain		20
Processing capacity	26	
Lack of or inadequate processing facilities		14
Absence of standards on quality and food safety		6
Low technical efficiency		6
Standards in quality/quality control	10	
Produce does not meet quality requirements		10
Investment capacity/credit access	12	
Absence of capital for investment		12

The literature review shows all the different causes leading to food loss. As described in this chapter, specific solutions (including technologies) can directly be linked to reducing these causes or their consequences. So, on the basis of how often a particular cause of food loss is mentioned, an estimate can be made of the extent to which a certain technology will contribute to reducing food loss (by reducing the cause or their consequences). When, for example, the literature review shows that in the processing stage of the supply chain the absence of cold chain infrastructure is mentioned as the relevant cause for food loss in 15 of the 65 researched reports and articles, we assume that the cold-storage technology has a relevance of 15/65 in the processing stage. Therefore, based on this research it is possible to assign a weight to specific technology, which helps reduce food loss along the supply chain realising that this is based on an indirect relation between causes of food loss and the technology in reducing these causes or their consequences. There are two rationales behind this approach. The first is that the order (not the weight) of impact of a certain technology on food waste reduction matches with the experience that experts from Wageningen University & Research have with many food waste studies and projects. The second is that one can argue that research is also 'demand driven'. If one technology has a higher impact on food waste reduction, it is more interesting to investigate its technical and financial feasibility than a technology with small impact. The study mentioned above is the most comprehensive literature review and we are therefore convinced that this method can be used to give a responsible estimate of the 'relevance of a technology' in the contribution to reducing food waste.

We show how to weigh the influence / relation of a certain technology to the expected food loss reduction for the Daikin and Stora Enso cases (see next section).

1.5 Cold storage

1.5.1 Selection of target companies

Daikin Industries was selected as a case study

We used the FactSet Revere data on companies in the segment of Air Conditioning and Refrigeration in combination with the description in the BOA[6] database to identify cold storage technology manufactures. Although finding manufactures or sellers of the key technologies in relation to reduction of food loss is not easy, we believe Daikin Industries Ltd is a company that can serve as 'test case'[7]. For Daikin we are looking at the equipment that Daikin produces and sells and that is only relevant when they are bought and used by cold storage contractors. So, we have an indirect relation that we unfortunately cannot avoid when we must focus on the companies in the UBS database. During the elaboration of the case study, we show how to correct for this 'indirect' impact.

Table 1.2 Overview Daikin

	Daikin Industries Ltd (Osaka, Japan)
	DAIKIN
	Daikin Industries, Ltd. is a Japanese multinational air conditioning manufacturing company headquartered in Osaka.
Total revenue	€28,455m end of February 2018 ($18.93bn USD in 2016)
Warehousing	Website: *'Ineffective control of temperature and humidity can adversely affect the quality and safety of goods being stored at warehouses. Air conditioning and refrigeration equipment play an essential role in maintaining the proper storage environment for products before shipment. With the significant energy savings and reliable operation offered by Daikin air conditioning equipment and systems, warehouses are increasingly choosing Daikin for an integrated approach to heating, cooling, and air quality control.'*
Food Processing & Storage	Website: *'Because the proof of the pudding is in the tasting, Daikin offers air conditioning solutions to the food industry in areas ranging from production to storage and distribution. As a comprehensive manufacturer, Daikin offers a 'total solution' that combines refrigeration, heating, air conditioning, and air handling systems to meet the strict demands of the food industry and deliver lower running costs. Our expertise even extends to refrigeration and freezer showcases in neighbourhood convenience stores.'*
Container Refrigeration	Website: *''Globalization of customer tastes further increases demands on container refrigeration, and our technology performs a vital role in the distribution of food products. For shipments of perishables from worldwide production centres to other regions for consumption, there is a demand for marine containers to finely control temperatures to protect products from freeze damage and moisture. Utilizing our 40 years of know-how, we are able to meet a wide range of temperature requirements from -30℃ to 30℃.''*
Employees	Europe, the Middle East, and Africa: 6,476 China: 13,824 Asia and Oceania: 10,149 Americas: 9,608 Japan: 11,341
Countries	It has operations in Japan, China, Australia, India, Philippines, Southeast Asia, Europe, North America, and South America.

6 The BOA database is a list – selected by UBS – of companies to include in the study.

7 There were no hard selection criteria except for the company to be in the FactSet Revere database and selling relevant technology.

1.5.2 Case study cold storage: Daikin Case

Focus is on Daikin air conditioning and refrigeration technology in Kenya

For Daikin we specify air conditioning and refrigeration technology used for storage of fruits and vegetables (i.e. in the processing stage of the supply chain of fruits and vegetables) in Kenya[8]. Table 1.7 shows the 'numbers' related to the variables needed for the methodology specified in Section 1.4.

56,517,225 kg food loss avoided by Daikin in Kenya in the processing stage in the fruits and vegetables sector

The 'OUTCOME local = 56,517,225 kg' which means 56,517,225 kg food loss is avoided by Daikin in Kenya in the processing stage. Dividing this by the revenue (or sales) of air conditioning and refrigeration technology in Kenya (73,585,427) we get 'OUTCOME_local_st = 7.68 kg/USD', which means food loss that is avoided for each USD in sales amounts to 7.68. Some variables are explained in more detail in the remainder of this section.

[8] Kenya was chosen as representative for a less developed country.

Table 1.7 Daikin case

Step		Description			Input	Data availability
1	T	Technology			Air conditioning and Refrigeration (Storage)	Selection / choice (UBS seg-rev database)
2	C	Company			Daikin	Selection UBS seg-rev database
2a	R	Country / Region			Kenya	UBS seg-rev database
	S_C	Annual Sales of Company C		$	16,472,066,426	UBS seg-rev database
2b&c	S_{CR}	Annual Sales ($) of company C in region R		$		UBS geo-rev database/Annual report
2c	S_{CRT}	Annual Sales ($) of T by C in R related to F&V (for all R where C sells)	$S_{CRT} = Y_{CTR} . Y_{CR} . S_C$	$	73,585,427	Calculation
2c	X_{CR}	Share (%) of F&V related sales of technology T of C in R		%		UBS geo-rev database/Annual report
	Y_{CR}	share (%) of sales of company C in region R			3.13%	UBS geo-rev database/Annual report
2c	Y_{CTR}	Share (%) of sales of T by C in region R		%	14.29%	See explanation below
3	L	Supply chain stage(s)			Processor	Consensus/Expert judgement/Company information
4a	P_R	Production of F&V in R		kg		FAOSTAT production data
4b	$\%FL_{RL}$	% of food loss of F&V in R by each supply chain stage L		%	25%	See Figure 6 in http://www.fao.org/docrep/014/mb060e/mb060e.pdf
4c	V_{CRT}	Volume of T by C in R related to F&V (for all R where C sells)	$V_{CRT} = U_{CRT} / Z$	kg	565,172,251	Calculation
4ci	Q	Cost per U of T for C		$ per 1.000m^3	$ 50,000	Here it is expert knowledge. For some countries an overview of many types of storage and their costs are available. This is very specific. General data availability is an issue.
4ci	U	Capacity for F&V of T		m^3	1,000	Here it is expert knowledge. General data availability is an issue.
4ci	U_{CRT}	Capacity of T by C in R related to F&V (for all R where C sells)	$U_{CRT} = (S_{CRT}/Q) * U$	m^3	1,471,709	Calculation
4cii	Z	Conversion of U to weight for T (... m^3 = 1000 Kg. F&V)		1.000Kg.	2.6	Conversion website http://www.tis-gdv.de/tis_e/ware/inhalt_gesamt.htm
4d	$\%FL_{LT}$	% of food loss of F&V when T is applied in R by each supply chain stage L		%	15%	Calculation plus see Figure 6 in http://www.fao.org/docrep/014/mb060e/mb060e.pdf
4e	TFL_{RL}	Food loss of F&V in R by stage L	$TFL_{RI} = V_{CRT} * \%FL_{RL}$	kg	141,293,063	Calculation
4f	TFL_{CRLT}	Food loss when technology T is applied at stage L in country R by company C	$TFL_{CRLT} = V_{CRT} * \%FL_{LT}$	kg	84,775,838	Calculation
4g	FLA_{CRT}	Food loss avoided by company C in R by using T	$FLA_{CRT} = \Sigma_L[TFL_{RL} - TFL_{CRLT}]$	kg	56,517,225	OUTCOME_local Calculation

Step 2c: determining share (%) of sales of T by C in R (**Y_{CTR}**)

14.29% of sales of the technology cold-storage (refrigeration) by Daikin in Kenya are relevant for fruits and vegetables

In the UBS FactRevere database can be found that 89.8% of the Daikin sales are related to the technology 'Air conditioning and Refrigeration' (S_C = Annual Sales of Company C = $16,472,066,426). This number, however, is still general because Daikin delivers this technology to more markets than just the fruits and vegetable sector. To obtain a figure that reflects the sales related to the relevant market, more information can, in this particular case, can be found in Daikin's annual report. Daikin reports that it produces 14 'sub-technologies'[9]. Of the 14 'sub-technologies' only two, 'Absorption refrigerators' and 'Turbo refrigerator equipment' are relevant for the *food supply chain* and thus our methodology. This two out of fourteen constitutes 14.29%, assuming equally distributed revenue across all 14 technologies. This percentage is not only specified per region, it is also based on food in general and thus not specific for fruits and vegetables. So, we assume this holds for the fruits and vegetables supply chain in Kenya: meaning **Y_{CTR} = 14.29%** (Share of sales of the technology cold-storage (refrigeration) by Daikin in Kenya).

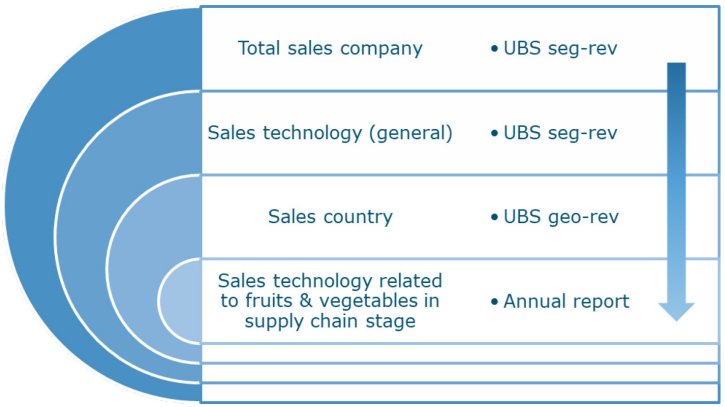

Figure 1.3 Process to determine Y_{CTR}

Step 4b: determining technology specific percentage of food loss (**$\%FL_{LT}$**)

Using weighting factors to represent impact of a technology in a proper way based on literature

Simply taking the frequency of a technology mentioned in an article is not representing its impact in a proper way. It has to be linked to where the technology is applied and to what level of certainty we think it will influence food loss. Hence weighing factors are introduced below to include this reasoning. Table 1.8 below shows four extra columns in comparison to Table 1.5 (page 12):

- Column C shows the relation of the specific technology related to food loss we are looking at. We 'score' if the technology 'refrigeration' causes food loss: 0 = no relation; 0.5 = sometimes relation; 1 = relation;
- In column D we evaluate if the cause (related to the specific technology 'refrigeration') can occur at the specific stage in the supply chain we are looking at. In this case: 'Processor'. 0 = no relation; 0.5 = sometimes relation; 1 = relation
- In column E the number of articles is multiplied with the score in 'Supply chain Stage: Processing' so this gives (based on the literature review) the number of reports and/or articles related to Food Loss Causes in the Processing stage of the supply chain for all causes, thus including refrigeration (calculated column B x D);
- In column F the number of articles where refrigeration is mentioned as a cause for food loss is given (calculated column B x C x E)

42% of the supply chain refrigeration technology effects food loss in the processing stage

The table shows that of all causes in the processing stage of the supply chain, refrigeration technology (in our case related to Daikin) can help in 41,87% (85/203) of the cases to reduce food loss in the fruit and vegetable chain. In all the other cases all matters that cause food loss cannot be directly linked to the relevant technology sold by Daikin, i.e. refrigeration. Causes are for example mismanagement, lack of market information, etc.

[9] The 14 technologies are room air-conditioning systems; air purifiers; heat-pump hot-water-supply and room-heating systems; packaged air-conditioning systems; multiple air-conditioning systems for office buildings; air-conditioning systems for facilities and plants; absorption refrigerators; freezers; water coolers; turbo refrigerator equipment; air-handling units; air filters; industrial dust collectors; marine-type container refrigeration

Table 1.8 Weighing factors for the technology 'refrigeration' in the processing stage of the supply chain of fruit and vegetables in developing countries based on van Gogh et al (2013)

Causes of post-harvest losses in fruit and vegetable supply chains in developing economies	# references	Technology: Refrigeration	Supply Chain Stage: Processing	Cause food loss at processing stage	Case: Daikin
A	B	C 0 = no relation; 0.5 = sometimes relation; 1 = relation	D 0 = no relation; 0.5 = sometimes relation;1 = relation	E (= B x D)	F (= B x C x E)
cold chain/transport climate control	65				
unsuitable/unfit transportation vehicles	36	0	0	0	0
absence of cold chain infrastructure	15	1	1	15	15
poor or limited cold chain infrastructure	7	1	1	7	7
pre-cooling	7	1	0	0	0
Storage facilities	66				
Availability of cold storage facilities	32	1	1	32	32
Large variation in storage performance / non-adaptive use	28	1	1	28	28
Occurrence of diseases and product damages / bacterial damage	6	0.5	1	6	3
Postharvest product handling	59				
Rough handling of produce	26	0	0	0	0
Poor handling of produce	25	0	0.5	12.5	0
Inefficient, outdated and low level of technology	8	0	0.5	4	0
Packaging	45				
Inadequate packaging in storage and transport	22	0	1	22	0
Low technology packaging	15	0	0.5	7.5	0
Inappropriate use of packaging	8	0	0.5	4	0
Infrastructure & connectivity	20				
Poor road quality	7	0	0	0	0
Little investment in infrastructure	13	0	0	0	0
Market information/product pricing	26				
General lack of market information	18	0	0.5	9	0
Peak season – low pricing	8	0	0	0	0
Education / R&D	20				
Limited or no education / skills of personnel working in postharvest chain	20	0	1	20	0
Processing capacity	26				
Lack of or inadequate processing facilities	14	0	1	14	0
Absence of standards on quality and food safety	6	0	1	6	0
Low technical efficiency	6	0	1	6	0
Standards in quality/quality control	10				
Produce does not meet quality requirements	10	0	1	10	0
Investment capacity/credit access	12				
Absence of capital for investment	12	0	0	0	0
Total				203	85

Food loss in processing stage can be reduced from 25% to 15% in Kenya if cold storage technology is applied

Current (2016) food loss in Kenya is 25% in the processing stage of the supply chain for fruits and vegetables, whereas in more developed countries, where – amongst other things – this technology is already applied in the fruits and vegetables supply chain, food loss is only 2%. If all causes of food loss are controlled in the processing stage of fruits and vegetables by this technology the percentage could drop from 25% to 2%. However, we just calculated that only 41,87% can be solved by the technology 'refrigeration' and hence only 41,87% of the gap between 25% and 2% can be reduced by implementing the technology 'refrigeration' in the processing stage, i.e. a reduction of food loss from 25% to 15%. So **$\%FL_{LT}$ = 15%** = % of food loss among fruits and vegetables when the technology of cold-storage (refrigeration) is applied in Kenya in the supply chain stage 'processing'.

1.5.3 Estimate impact: contribution of food loss avoided due to cold storage to food availability

470000 Kenyans can be fed with the 49,735,158 kg avoided food loss of fruits and vegetables

In Kenya the avoided food loss in fruits and vegetables by Daikin equals 56,517,225 kg. FAOSTAT shows that about 88% (= **$\%C_{R}$**) of the production is for human consumption in Kenya, which comes down to 49,735,158 kg additional supply of fruits and vegetables. Based on FAOSTAT the annual Kenyan consumption with respect to fruits and vegetables is about 105kg (= **C_{FVR}**). Therefore, approximately 0.47m people (49,735,158/105=473,668m people) can be fed by the avoided food loss among fruits and vegetables. In 2017 Kenya had 47.7m inhabitants, so this number represents approximately 1% of the total population.

1.6 Packaging

1.6.1 Selection of target companies

Stora Enso was selected as a case study as it is the only company producing food loss related technology

Within the BOA database no suitable company could be found. The companies related to packaging in the BOA database all focus on consumer packaging, meaning that their technology is linked to food waste instead of food loss. In the overall database the company Stora Enso is listed. Stora Enso produces corrugated packaging and thus is suited for our methodology development.

Table 1.3 Overview Stora Enso

	Stora Enso Oyj (Helsinki, Finland)
	The renewable materials company Stora Enso develops and produces solutions based on wood and biomass for a range of industries and applications worldwide.
Total revenue	In 2017, Stora Enso's total revenue was 10.1bn euros.
Packaging	Website: '*Stora Enso annual production capacity:* - *5.9m tonnes of chemical pulp* - *5.4m tonnes of paper* - *4.7m tonnes of board* - ***1.4bn square metres of corrugated packaging*** - *5.6m cubic metres of sawn wood products, including 2.6m cubic metres of value-added products.'*
Employees	On 31 December 2016, Stora Enso had 25,447 (25,680) employees in the group. The average number of employees in 2016 was 26,269, The numbers include 50% of employees at Veracel in Brazil and Montes del Plata in Uruguay.
Countries	It has operations in Finland, Sweden, China, Austria, Baltic countries, Belgium, Brazil, Czech Republic, Germany, The Netherlands, Poland, Russia, Uruguay, USA

1.6.2 Case study packaging: Stora Enso case

Focus is on packaging fruit and vegetables in Kenya

For Stora Enso we formulated the following case: the use of corrugated packaging material (technology) for fruit and vegetables (i.e. in the processing stage of the supply chain) in Kenya. Table 10 shows the 'numbers' related to the variables needed for the methodology specified in 3.4.

3,429,903 kg. food loss avoided by Stora Enso in Kenya in the processing stage in fruits and vegetables sector

The 'OUTCOME_local = 3,429,903 kg' which means 3,429,903 kg food loss is avoided by Stora Enso in Kenya in the processing stage. Dividing this by the revenue (or sales) of air conditioning and refrigeration technology in Kenya (5,238,243) we get 'OUTCOME_local_st = 0.66 kg/USD', which means that the food loss avoided for each USD in sales is 0.66 kg. Some variables are explained in more detail in the remainder of this section.

Table 1.4 Stora Enso case

Step		Description			Input	Data availability
1	T	Technology			Packaging	Selection / choice (UBS database)
2	C	Company			Stora Enso	Selection UBS seg-rev database
2a	R	Country / Region			Kenya	UBS seg-rev database
	S_C	Annual Sales of Company C		$	1,476,393,206	UBS seg-rev database
2b&c	S_{CR}	Annual Sales ($) of company C in region R		$		UBS geo-rev database/Annual report
2c	S_{CRT}	Annual Sales ($) of T by C in R related to F&V (for all R where C sells)	$S_{CRT} = Y_{CTR} . Y_{CR} . S_C$	$	5,238,243	Calculation
2c	X_{CR}	Share (%) of F&V related sales of C in R		%		UBS geo-rev database/Annual report
	Y_{CR}	share (%) of sales of company C in region R			3.55%	UBS geo-rev database/Annual report
2c	Y_{CTR}	Share (%) of sales of T by C in region R		%	10%	See explanation below
3	L	Supply chain stage(s)			Processor	Consensus/Expert judgement/Company information
4a	P_R	Production of F&V in R		kg		FAOSTAT production data
4b	$\%FL_{RL}$	% of food loss of F&V in R by each supply chain stage L		%	25%	See Figure 6 in http://www.fao.org/docrep/014/mb060e/mb060e.pdf
4c	V_{CRT}	Volume of T by C in R related to F&V (for all R where C sells)	$V_{CRT} = U_{CRT} / Z$	kg	81,470,371	Calculation
4ci	Q	Cost per U of T for C		$ per box (0.0324 m^3)	$ 0,80	Here it is expert knowledge. For some countries an overview of many types of storage and their costs are available. This is very specific. General data availability is an issue.
4ci	U	Capacity for F&V of T		m^3	0.0324	Here it is expert knowledge. General data availability is an issue.
4ci	U_{CRT}	Capacity of T by C in R related to F&V (for all R where C sells)	$U_{CRT} = (S_{CRT}/Q) * U$	m^3	212,149	Calculation
4cii	Z	) Conversion of U to weight for T (… m^3 = 1000 Kg. F&V)		1.000 Kg.	2.6	Conversion website http://www.tis-gdv.de/tis_e/ware/inhalt_gesamt.htm
4d	$\%FL_{LT}$	% of food loss of F&V when T is applied in R by each supply chain stage L		%	21%	Calculation and Figure 6 in http://www.fao.org/docrep/014/mb060e/mb060e.pdf
4e	TFL_{RL}	Food loss of F&V in R by stage L	$TFL_{RI} = V_{CRT} * \%FL_{RL}$	kg	20,367,593	Calculation
4f	TFL_{CRLT}	Food loss when technology T is applied at stage L in country R by company C	$TFL_{CRLT} = V_{CRT} * \%FL_{LT}$	kg	16,937,690	Calculation
4g	FLA_{CRT}	Food loss avoided by company C in R by using T	$FLA_{CRT} = \Sigma_L[TFL_{RL} - TFL_{CRLT}]$	kg	3,429,903	OUTCOME_local Calculation

Step 2c: determining share (%) of sales of T by C in R (**Y_{CTR}**)

12.24% of sales of the technology (corrugated packaging) by Stora Enso in Kenya are relevant for fruits and vegetables

It can be found in the UBS database that 12.24% of the Stora Enso revenues sales are related to the technology 'Paper Packaging Products' (S_C = Annual Sales of Company C = $ 14,76,393,206). This number, however, is still general because Stora Enso delivers this technology to more markets than just the fruit and vegetable sector. A figure that reflects the sales related to the relevant market can be found in Stora Enzo's annual report. Stora Enso reports that it produces 10 'sub-technologies'[10]. Of these 10 'sub-technologies' only one, 'Postal and transport packaging' is relevant for the food supply chain. This is two out of fourteen -- 10%. This percentage is not specified per region, so we assume this holds for the fruits and vegetables supply chain in Kenya: meaning **Y_{CTR} = 10%** (Share of sales of the technology packaging by Stora Enso in Kenya)

Step 4b: determining technology-specific percentage of food loss (**$\%FL_{LT}$**)

Using weighting factors to represent impact of a technology in a proper way based on literature

Simply taking the frequency of a technology mentioned in an article is not representing its impact in a proper way. It has to be linked to where the technology is applied and to what level of certainty we think it will influence food loss. Hence weighing factors are introduced below to include this reasoning. Table 1.11 below shows four extra columns in comparison to Table 1.5 (page 12):

- Column C shows the relation of the specific technology related to food loss we are looking at. We 'score' if the technology 'refrigeration' causes food loss: 0 = no relation; 0.5 = sometimes relation; 1 = relation;
- In column D we evaluate if the cause (related to the specific technology 'refrigeration') can occur at the specific stage in the supply chain we are looking at. In this case: 'Processor'. 0 = no relation; 0.5 = sometimes relation; 1 = relation
- In column E the number of articles is multiplied with the score in 'Supply chain Stage: Processing' so this gives the number of articles related to Food Loss Causes in the Processing stage of the supply chain for all causes, thus including refrigeration (calculated column B x D);
- In column F the number of articles where refrigeration is mentioned as a cause for food loss is given (calculated column B x C x E)

18% of the supply chain refrigeration technology affects food loss in the processing stage

The table shows that of all causes in the processing stage of the supply chain packaging technology (in our case related to Stora Enso) it can help in 18.28% (40.5/221.5) of the cases.

[10] The 10 technologies are: Retail-ready and shelf-ready packaging; Food and beverage; Consumer goods and electronics; Paper products; Industrial packaging; Postal and transport packaging; E-commerce; Stands and promotional packaging and solutions; Second life solutions; Intelligent packaging

Table 1.5 Weighing factors for the technology 'packaging' in the processing stage of the supply chain of fruit and vegetables in developing countries based on van Gogh et al (2013)

Causes of post-harvest losses in fruit and vegetable supply chains in developing economies		# references	Technology: packaging	Supply Chain Stage: Processing	Cause food loss at processing stage	Case: Stora Enso
A		B	C 0 = no relation; 0.5 = sometimes relation; 1 = relation	D 0 = no relation; 0.5 = sometimes relation;1 = relation	E (= B x D)	F (= B x C x E)
cold chain/transport climate control	65					
unsuitable/unfit transportation vehicles		36	0	0	0	0
absence of cold chain infrastructure		15	0	1	15	0
poor or limited cold chain infrastructure		7	0	1	7	0
pre-cooling		7	0	0	0	0
Storage facilities	66					
Availability of cold storage facilities		32	0	1	32	0
Large variation in storage performance / non-adaptive use		28	0	1	28	0
Occurrence of diseases and product damages / bacterial damage		6	0	1	6	0
Postharvest product handling	59					
Rough handling of produce		26	0	0	0	0
Poor handling of produce		25	0	0.5	12.5	0
Inefficient, outdated and low level of technology		8	0	0.5	4	0
Packaging	45					
Inadequate packaging in storage and transport		22	1	1	22	22
Low technology packaging		15	0.5	1	15	7.5
Inappropriate use of packaging		8	0.5	1	8	4
Infrastructure & connectivity	20					
Poor road quality		7	1	1	7	7
Little investment in infrastructure		13	0	0	0	0
Market information/product pricing	26					
General lack of market information		18	0	0.5	9	0
Peak season – low pricing		8	0	0	0	0
Education / R&D	20					
Limited or no education / skills of personnel working in postharvest chain		20	0	1	20	0
Processing capacity	26					
Lack of or inadequate processing facilities		14	0	1	14	0
Absence of standards on quality and food safety		6	0	1	6	0
Low technical efficiency		6	0	1	6	0
Standards in quality/quality control	10					
Produce does not meet quality requirements		10	0	1	10	0
Investment capacity/credit access	12					
Absence of capital for investment		12	0	0	0	0
Total					221.5	40.5

Food loss in processing stage can be reduced from 25% to 21% in Kenya if corrugated packaging technology is applied

We saw that the current food loss in Kenya is 25% in the processing stage of the supply chain for fruits and vegetables. In the developed countries where this technology – amongst other things – is applied, this food loss is only 2%. If all causes leading towards food loss are tackled by this technology in the processing stage of fruits and vegetables, this percentage could go from 25% to 2%. However, we just calculated that only 18.28% can be solved by the technology 'packaging' and hence only 18.82% of the gap between 25% and 2% can be reduced by implementing the technology 'packaging' in the processing stage, i.e. a reduction of food loss from 25% to 21%.

1.6.3 Estimate impact: contribution of food loss avoided due to packaging to food availability

29,000 Kenyans can be fed with the 3,018,314 kg of avoided food loss among fruits and vegetables

In Kenya the avoided food loss in fruits and vegetables by Stora Enso equals 3,429,903 kg. FAOSTAT shows that about 88% (= $\boldsymbol{\%C_R}$) of the production is for human consumption in Kenya, which is 3,018,314 kg additional food supply in fruits and vegetables. Based on FAOSTAT, the annual intake with respect to fruits and vegetables is about 105 kg. (= $\boldsymbol{C_{FVR}}$). Therefore, approximately 0.029m people (3,018,314/105=28,745 people) can be fed by the avoided food loss among fruits and vegetables. In 2017 Kenya had 47.7m inhabitants, so this number represents approximately 0.006% of the total population.

1.7 Summary of the methodology

1.7.1 Calculation structure

Based on the case studies and the availability of data in the UBS databases the methodology is:

$$OUTCOME\_local = FLA_{CRT} = TFL_{RL} - TFL_{CRLT}$$

or

$$OUTCOME\_Local = FLA_{CRT} = \left(\frac{S_{CRT}}{\frac{Q}{1{,}000} * Z}\right) * (\%FL_{RL} - \%FL_{LT})$$

and

$$OUTCOME\_local\_\boldsymbol{st} = \frac{OUTCOME\_local}{S_{CRT}}$$

Step		Description			Data availability
1	T	Technology			Selection / choice (within UBS seg-rev database)
2	C	Company			Selection within UBS seg-rev database
2a	R	Country / Region			Selection within UBS seg-rev database
2b	S_C	Annual Sales of Company C		$	UBS seg-rev database
2c	S_{CRT}	Annual Sales ($) of T by C in R related to F&V (for all R where C sells)	$S_{CRT} = Y_{CTR} . Y_{CR} . S_C$	$	Calculation
2d	Y_{CR}	share (%) of sales of company C in region R			UBS geo-rev database
2e	Y_{CTR}	Share (%) of sales of T by C		%	Additional information from annual reports
3	L	Supply chain stage(s)			Consensus/Expert judgement/Company information
4a	$\%FL_{RL}$	% of food loss of F&V in R by each supply chain stage L		%	See Figure 6 in http://www.fao.org/docrep/014/mb060e/mb060e.pdf
4b	V_{CRT}	Volume of T by C in R related to F&V (for all R where C sells)	$V_{CRT} = U_{CRT} / Z$	kg	Calculation
4c	Q	Cost per U of T for C		$ per m^3)	Expert knowledge. For some countries an overview of many types of storage and their costs are available. This is very specific. General data availability is an issue.
4ci	U	Capacity for F&V of T		m^3	Expert knowledge. General data availability is an issue.
4ci	U_{CRT}	Capacity of T by C in R related to F&V (for all R where C sells)	$U_{CRT} = (S_{CRT}/Q) * U$	m^3	Calculation
4cii	Z	Conversion of U to weight for T (… m^3 = 1000 Kg. F&V)	2.6	1.000kg	Conversion website http://www.tis-gdv.de/tis_e/ware/inhalt_gesamt.htm
4d	$\%FL_{LT}$	% of food loss of F&V when T is applied in R by each supply chain stage L		%	http://www.fao.org/docrep/014/mb060e/mb060e.pdf (Figure 6) and calculation
4e	TFL_{RL}	Food loss of F&V in R by stage L	$TFL_{Rl} = V_{CRT} * \%FL_{RL}$	kg	Calculation
4f	TFL_{CRLT}	Food loss when technology T is applied at stage L in country R by company C	$TFL_{CRLT} = V_{CRT} * \%FL_{LT}$	kg	Calculation
4g	FLA_{CRT}	Food loss avoided by company C in R by using T	$FLA_{CRT} = \Sigma_L[TFL_{RL} - TFL_{CRLT}]$	kg	Calculation (= OUTCOME_local)
		OUTCOME_local_st	OUTCOME_local / S_{CRT}		Calculation (= Normalised OUTCOME)

The methodology is developed in such a way that it can be used for all companies and all the relevant technologies. In the context of this research the companies are related to the technologies 'cold storage' and 'packaging'. Changing the company and/or the technology also changes the parameters. The table below shows which variables are company and/or technology dependent (+) meaning that specific information is needed vis-à-vis company and/or technology.

Table 1.6 Dependency between input and Company and/or Technology

Inputs	Description	Source	Dependency	
			Technology	Company
Y_{CTR}	Share (%) of sales of Technology by C in R	Additional information needed	+	+
Y_{CR}	Share (%) of sales of company C in region R	UBS geo-rev Database	-	+
S_C	Annual Sales of Company C	UBS seg-rev Database	-	+
Q	Cost per capacity U of technology T for company C	Expert knowledge	+	+
Z	Conversation of U to weight for T (1 m^3 = ... kg F&V)	Conversion website http://www.tis-gdv.de/tis_e/ware/inhalt_gesamt.htm	-	-
$\%FL_{RL}$	% of food loss of F&V in R by each supply chain stage L	See Figure 6 in http://www.fao.org/docrep/014/mb060e/mb060e.pdf	-	-
$\%FL_{LT}$	% of food loss of F&V when T is applied in R by each supply chain stage L	http://www.fao.org/docrep/014/mb060e/mb060e.pdf & Literature review (Van Gogh et al., 2013)	+	-

'-' = no dependency and '+' = dependency

1.7.2 Sensitivity analysis based on the Daikin Case

Sensitivity analysis assuming a theoretical statistical distribution for the technology impact estimate

The sensitivity analysis described in the project proposal is 'Estimation of variance in estimated actual impact of the case study companies based on variance in average impact of technologies to identify the potential range of value'. There is not much data on the impact of technologies. Given the uncertainty in the technology impact in our food loss methodology, there are two ways to get a better/more complete picture: we can gather many estimates of the impact of a certain technology on food loss (from literature, experts, one-of study etc.) and estimate a variance in those values, or we can assume a theoretical statistical distribution for the technology impact estimate. We choose the latter.

Taking into account variances in outcomes using intervals around model parameter values

Variance in outcome (and by revenue proxy on IMPACT) can be assessed using a simple ±5, 10 and 15% interval around the assumed values of model parameters in the food loss mathematical function:

$$OUTCOME\_Local = FLA_{CRT} = \left(\frac{S_{CRT}}{\frac{Q}{1{,}000} * Z}\right) * (\%FL_{RL} - \%FL_{LT})$$

Where

$$S_{CRT} = Y_{CRT} * Y_{CR} * S_C$$

With:

- Y_{CRT} = share (%) of sales of T by C in region R
- Y_{CR} = Share (%) of sales of company C in region R
- S_C = Annual Sales of Company C

This makes the mathematical function as follows:

$$OUTCOME\_Local = FLA_{CRT} = \left(\frac{Y_{CRT} * Y_{CR} * S_C}{\frac{Q}{1{,}000} * Z}\right) * (\%FL_{RL} - \%FL_{LT})$$

Using mathematical sensitivity analyses to establish an indicator of variances

The suitable analysis is due to the mathematical function a sensitivity analysis based on the quotient of variance in FLA_{CRT} and variance of variables. Using the combinations of values from the possible ranges for the parameters gives us a range of possible outcomes. This can be used as an indicator of variance in the outcomes owing to uncertainty regarding parameter values. We start with variation in one variable at a time. This is a deterministic simulation with monotony in the relation of each variable and the output. There is no complex analysis required nor assumption made about distributions.

Table 1.7 The 'original' parameter settings for the Daikin case

S_C (in millions)	Q	Z	%FL_{RL}	%FL_{LT}	Y_{CTR}	Y_{CR}
$16,472.07	$5,000.00	2.60	25.0%	2.0%	20%	3.1%

Applying these deviations per parameter leads to the parameter settings in Table 1.14.

Table 1.8 Parameter settings at incremental deviations applied to all parameters

Deviation	S_C (in millions)	Q	Z	%FL_{RL}	%FL_{LT}	Y_{CTR}	Y_{CR}
-15%	$14,001.26	$4,250.00	2.21	21.3%	1.7%	17%	2.7%
-10%	$14,824.86	$4,500.00	2.34	22.5%	1.8%	18%	2.8%
-5%	$15,648.46	$4,750.00	2.47	23.8%	1.9%	19%	3.0%
0%	*$16,472.07*	*$5,000.00*	*2.60*	*25.0%*	*2.0%*	*20%*	*3.1%*
5%	$17,295.67	$5,250.00	2.73	26.3%	2.1%	21%	3.3%
10%	$18,119.27	$5,500.00	2.86	27.5%	2.2%	22%	3.4%
15%	$18,942.88	$5,750.00	2.99	28.8%	2.3%	23%	3.6%

Next, we calculated the value for FLA_{CRT} for the variation corresponding to the specific parameter. This means that every cell in the table below shows the FLA_{CRT}. For example: the first cell gives a FLA_{CRT} when the SC is minus 15% = 155m tonnes (see Table 1.15 below).

Table 1.9 FLA_{CRT} (million tonne) calculated for each scenario

	S_C	Q	Z	%FL_{RL}	%FL_{LT}	Y_{CTR}	Y_{CR}
-15%	155	214	214	152	184	155	155
-10%	164	202	202	162	184	164	164
-5%	173	192	192	172	183	173	173
0%	*182*	*182*	*182*	*182*	*182*	*182*	*182*
5%	191	173	173	192	181	191	191
10%	200	165	165	202	180	200	200
15%	209	158	158	212	180	209	209

Next the difference in FLA_{CRT} in relation to the 'original FLA_{CRT} ' is calculated. Table 1.19 shows what happens if one variable varies with some percentage.

Table 1.10 Difference of FLA_{CRT} (million tonne)

	S_C	Q	Z	%FL_{RL}	%FL_{LT}	Y_{CTR}	Y_{CR}
-15%	27	-32	-32	30	-2	27	27
-10%	18	-20	-20	20	-2	18	18
-5%	9	-10	-10	10	-1	9	9
0%	*0*	*0*	*0*	*0*	*0*	*0*	*0*
5%	-9	9	9	-10	1	-9	-9
10%	-18	17	17	-20	2	-18	-18
15%	-27	24	24	-30	2	-27	-27

Based on the calculated difference in Table 1.19 the percentagewise difference is calculated.

Table 1.11 Percentage difference of FLA_{CRT}

	S_C	Q	Z	$\%FL_{RL}$	$\%FL_{LT}$	Y_{CTR}	Y_{CR}
-15%	15.00%	-17.65%	-17.65%	16.30%	-1.30%	15.00%	15.00%
-10%	10.00%	-11.11%	-11.11%	10.87%	-0.87%	10.00%	10.00%
-5%	5.00%	-5.26%	-5.26%	5.43%	-0.43%	5.00%	5.00%
0%	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
5%	-5.00%	4.76%	4.76%	-5.43%	0.43%	-5.00%	-5.00%
10%	-10.00%	9.09%	9.09%	-10.87%	0.87%	-10.00%	-10.00%
15%	-15.00%	13.04%	13.04%	-16.30%	1.30%	-15.00%	-15.00%

The quotient of the variation in FLA_{CRT} divided by the variation in the variable is an estimate/indicator for the sensitivity.

Table 1.12 Estimation/indicator for the sensitivity of each parameter on FLA_{CRT}

	S_C	Q	Z	$\%FL_{RL}$	$\%FL_{LT}$	Y_{CTR}	Y_{CR}
-15%	1	1.18	1.18	1.08695652	0.086957	1	1
-10%	1	1.11	1.11	1.08695652	0.086957	1	1
-5%	1	1.05	1.05	1.08695652	0.086957	1	1
0%							
5%	1	0.95	0.95	1.08695652	0.086957	1	1
10%	1	0.91	0.91	1.08695652	0.086957	1	1
15%	1	0.87	0.87	1.08695652	0.086957	1	1
	1.00	**1.18**	**1.18**	**1.09**	**0.09**	**1.00**	**1.00**

Multiplicative effects of variable uncertainties

If we vary not only one variable each time as done above, but consider all combinations of variables, this will give insight in the multiplicative effects of variable uncertainties. Although the structure of the formula is simple and proportional variation for the variables S_{CRT}, Q and Z are straightforward with respect to sensitivity, the complete set of variations has been analysed. For each of the five variables S_{CRT}, Q, Z, $\%FL_{RL}$ and $\%FL_{RT,}$ three cases are analysed: -15%, 0% and 15% deviation of the reference data value. Obviously 3^5=243 combinations are possible and for any of them the quotient of the new Food Loss Avoided (FLA_{CRT} – new) and the reference Food Loss Avoided (FLA_{CRT} – ref.) is calculated by dividing the former by the latter. The result is shown in the table below where we took ranges of quotient and the number of cases that fall in these ranges. The third column shows the share of cases that fall in the different range quotients.

Table 1.19 Quotient ranges considering all combinations of variables

range quotient	# cases	share
0.5-0.6	3	1%
0.6-0.7	12	5%
0.7-0.8	30	12%
0.8-0.9	48	20%
0.9-1.1	57	23%
1.1-1.2	48	20%
1.2-1.4	30	12%
1.5-1.8	12	5%
1.8-1.9	3	1%
	243	**100%**

The sensitivity analysis shows a range of 20% around the reference value for food loss avoided

Based on the calculations where we only change one variable each time as done above, Table 1.18 showed that the quotient lies between 0.09 (= $\%FL_{LT}$) and 1.18 (Q and Z). From Table 1.19 it follows that for 63% of all combinations the quotient also lies between 0.8 and 1.2. This relates to a range of 20% around the reference value for $FLA_{CRT,}$ which means the variations in the variable impact the outcome of the formula in most cases only in a range of 20%.

In 87% of cases the range of 30% around the reference value for food loss avoided is not exceeded The more 'extreme' range of 30% around this reference value for FLA_{CRT} is not exceeded in 87% of the cases (so, 13% of the cases are within this 30% range). This means that this will occur in only a small number of cases *where all variable variations deviate in the same direction.* When running all the combinations we see a minimum quotient of

0.53 and a maximum quotient of 1.87 of the original Food Loss Avoided. The overall conclusion is thus that the multiplicative effect is not expected to add significant additional sensitivities compared to the single variable analysis. In addition, comparing two companies in most cases will show a different order of the output in which case the impact of variable variation is relatively small, hence will not affect the result of what company performs better.

The impact of the variation in the variables on the outcome is small in all cases

As can be seen from the formula, sensitivity is proportional (linear or reciprocal) in most variables except $\%FL_{LT}$, whereby the impact of variation is relatively small in all cases. Order size will not change dramatically. The same holds when we perform the sensitivity analysis for combinations of variations in input variables.

1.7.3 Key assumptions

Four assumptions to take into account vis-à-vis the indirect relation between technology and food loss avoided. As described earlier there is an indirect relation between technology and food loss avoided. This leads to four key assumptions:

$$OUTCOME\_Local = FLA_{CRT} = \left(\frac{Y_{CRT} * Y_{CR} * S_C}{\frac{Q}{1{,}000} * Z}\right) * (\%FL_{RL} - \%FL_{LT})$$

Assumption one is that each technology's sales are equally distributed per region

The first assumption is about the distribution of sales per region. In the UBS database there are company sales shares per region and per technology/subdivision, however not per combination. Hence a key assumption is that each technology's sales are equally distributed per region. This influences the variable: $\mathbf{Y_{CR}}$ = share of sales of the specific company in the relevant country.

Assumption two is that the percentage of total sales linked to the category food also applies to the subcategory of fruits and vegetables

The second key assumption is related to the interpretation of the specific classification of each technology and 'sub-technology' that is relevant for the products we are studying. For example, we assume that the technology classification 'cold storage' means cooling technology for food and non-food, and that food refers to for example potatoes, fruits, etc. We sourced additional information from annual reports of the two case study companies. For each 'relevant sub-technologies' we calculate what percentage of the total sales can be linked to food and assume that this can also be applied to the subcategory fruits and vegetables.

This influences the variable: $\mathbf{Y_{CTR}}$ = share of sales of the relevant technology by the company in the specific country.

Assumption three is that the percentage of food loss avoided due to a specific technology can be estimated based on literature

The third key assumption is related to technology-specific percentage of food loss. The available food loss numbers per country are related to product groups and supply chain stage. The relation to the technology used is not known. Based on extensive literature research we give a weight to the influence that a specific technology has on the reduction of food loss in the part of the supply chain of interest. This influences the variable: $\mathbf{\%FL_{LT}}$ = % of food loss among fruits and vegetables when the relevant technology packaging is applied in the specific country in the chosen supply chain stage.

Assumption four is that food loss percentage in developed countries poses the proper best case scenario

The fourth assumption is related to the third; we compare food loss in situations in which a specific technology is implemented and compare it to the situation where this is not the case. Meaning that we compare the current situation in a specific country (the baseline) to the situation in developed countries (i.e. the situation where the technology is fully implemented). Therefore, we take a 'best case scenario' to compare the technology application level to the current (baseline) situation. This influences the variable: $\mathbf{\%FL_{LT}}$ = % of food loss among fruits and vegetables when the relevant technology packaging is applied in the specific country in the chosen supply chain stage.

Assumption five is that conversion from volume to weight is classified correctly based on most common fruits and vegetables
The fifth key assumption is related to the conversion from volume to weight. This average conversion factor is based on the top 13 fruits and top 12 vegetables relevant for all the developing countries. This influences the variable: **Q** = cost for unit capacity of the relevant technology sold by the specific company to 'handle' fruits and vegetables (volume).

1.8 Conversion factors: transform revenues to outcome and impact?

Conversion from revenues to outcome
The OUTCOME_local_**st** = OUTCOME_local / S_{CRT} gives a 'conversion factor' of the sales of the relevant technology related to fruits and vegetables and sold by the specific company in the country under study. For the 'cold-storage' case of Daikin the conversion is 7.86 kg/USD food loss avoided for every dollar of sales in Kenya. For the technology packaging this would be 0.655 kg/USD.

Question: Does this mean that if we know the annual sales of 'cold-storage' technology (Y) of company X in Kenya we can assume that the amount of fruit and vegetable in the processing stage of food loss avoided is Y * 7.86 kg/USD?

Conversion from revenue to impact
The impact is for Kenya related to fruit and vegetables: (OUTCOME_local *0.88%) / 105 kg = OUTCOME_local / 119.32. So, the factor is 0.00838 extra people fed by each kg avoided of fruit and vegetable food loss in Kenya (Y-cold_storage * 0.00838). For the technology packaging this would be Y-Packaging * 0.0054889.

Question: Would this mean for the annual sales of 'cold-storage' technology (Y) of company X in Kenya that the impact, i.e. extra people fed, would be Y * 0.00838?

For both questions the answer is negative. While the methodology is generic, i.e. usable for both technologies, besides the key assumptions and thus the limitations of the methodology, the parameters are very specific when it comes to the company and the technology sold. The conversion factors would only be usable if they are applied to exactly the same type of company, with exactly the same type of technology, used in the same country within the same stage of the supply chain. A simple conversion number from sales data to impact is not realistic because this will include all the company-, technology- and country-specific inputs.

However, a conversion formula can be given in which all the all the company-, technology- and country-specific inputs will be implemented for each different situation and therefore the outcome will be unique for the given situation:

$$\text{Impact} = \frac{Y_{CTR} * Y_{CR} * S_c * U * (\%FL_{RL} - \%FL_{LT}) * \%C_R}{Q * Z * C_{FVR}} \text{ people}$$

or

$$Impact = \frac{\left(\left(\frac{Y_{CRT} * Y_{CR} * S_C}{\left(\frac{Q}{1{,}000}\right) * Z}\right) * (\%FL_{RL} - \%FL_{LT})\right) * \%C_R}{C_{FVR}} \, people$$

Where
- **$\%C_R$** equals the share of the available fruits and vegetables in region R that is going to national consumption, and
- **C_{FVR}** is the annual consumption of fruits and vegetables in region R in kg

This can be applied to both cases: Daikin and Stora Enso.

Table 1.13 Dependency between input and company and/or technology

Inputs	Description	Source	Dependency	
			Technology	Company
Y_{CTR}	Share (%) of sales of Technology by C in R	Additional information needed	+	+
Y_{CR}	Share (%) of sales of company C in region R	UBS geo-rev Database	-	+
S_C	Annual Sales of Company C	UBS seg-rev Database	-	+
U	*Capacity for Fruit & Vegetables of Technology T*	*Expert knowledge*	+	-
Q	Cost per capacity U of technology T for company C	Expert knowledge	+	+
Z	Conversation of U to weight for T (1 m^3 = ... kg F&V)	Conversion website http://www.tis-gdv.de/tis_e/ware/inhalt_gesamt.htm	-	-
$\%FL_{RL}$	% of food loss of F&V in R by each supply chain stage L	http://www.fao.org/docrep/014/mb060e/mb060e.pdf (Figure 6)	-	-
$\%FL_{LT}$	% of food loss of F&V when T is applied in R by each supply chain stage L	http://www.fao.org/docrep/014/mb060e/mb060e.pdf & Literature review (Gogh, 2013)	+	-
$\%C_R$	Share of the available fruits and vegetables in region R that is going to national consumption	FOASTAT	-	-
C_{FVR}	Annual consumption of fruits and vegetables in region R in kg	FOASTAT	-	-

'-' = no dependency and '+' = dependency

1.9 Discussion and next steps: ideas to improve methodology and to widen the scope to include other technologies

The goal of the project is to develop a methodology to assess the impact of companies rated on the stock exchange in terms of food security. Food security is related to increased food supply and in this project is driven by national production, international trade and food loss reduction. In addition, this assessment should be based on information about these companies that is available to UBS. This can be revenue-based information that can be split into various technological divisions of the company *or* regions. However, other (open source) information can be used, like annual reports.

For the methodology to evaluate companies with respect to food security, UBS should consider the following:

a. It must be self-supporting and not dependent on additional information where the company must be contacted.
b. The input data should be as uniform as possible (same interpretation/definition for all companies)
c. The input data should be linked to food security
d. The input data should be accessible:
   a. Revenue-based data
   b. Open-access data (website, annual report)

UBS owns financial data on the sales of many companies, hence these data are the primary source. They meet the above-mentioned criteria a), b) and d). In the methodology for food loss, based on logical reasoning, the revenue-based data are linked to food security, so condition c) was met as well. However, after feedback from relevant companies this linkage turned out to be questionable. It would be best to ask the companies what data can be considered as predictive for food loss in a certain region for a certain technology, but this contravenes condition a).
Other company input data can be found on the internet or in annual reports, but these will not satisfy condition b) in most cases.

Conclusion:

1. The methodology requires an additional condition:
    e. The linkage in c) should be validated as supportive of food security without contacting the company
2. The revenue data in the UBS database are not sufficient to satisfy condition c) and e)
3. Other (open access) data in most cases do not satisfy condition b)

Next steps

Deus ex Machina: there is another open source with uniform data on companies that satisfies all conditions. The probability to find such a source is very low. The second-best option is to find a set of proxies that on the one hand have a validated linkage to food loss and on the other hand are most likely to contain at least one proxy that is available in the publicly accessible information of a medium to large company.

On a meta-level the feasibility of the methodology differs per company. This is related to the product/ added value of the company. In some cases, the relation between the product/added value is straightforward. For example, it can be assumed that there is a huge correlation between sales of a fertiliser and horticulture production. However, production of cardboard boxes has many sales channels apart from food. In general every step and assessment of the level of 'connectivity' between input and output of that step is advisable.

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