Sustainability concepts in food processing

Techane Bosona & Girma Gebresenbet

Swedish University of Agricultural Sciences, Department of Energy and Technology

Uppsala (Sweden)

techane.bosona@slu.se
girma.gebresenbet@slu.se

Outline

The main contents include:

1. General aspects
2. Environmental impacts of selected organic produces
3. Economic aspects of selected organic produces

Learning Outcomes

The main learning outcomes are:

i. Understanding the general concept of sustainability in food value chains
ii. Understanding the influence of food processing on environmental impact
iii. Understanding the influence of food processing on food production cost
iv. Increased knowledge on Life Cycle Analysis (LCA) and Life Cycle Cost Analysis (LCCA) tools and their application for evaluation of organic food value chains

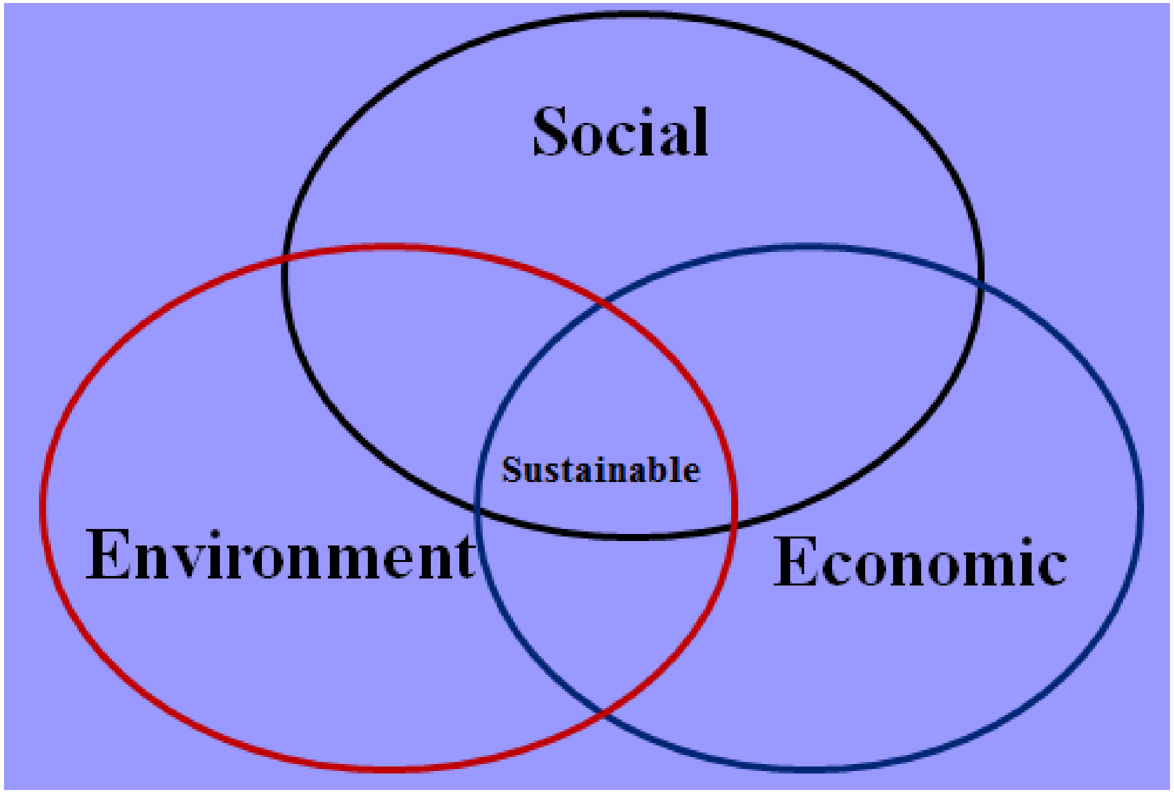
8.1. General aspects of sustainability in food production

- Sustainability in food value chain (FVC) is becoming challenging due to increasing world population, urbanization, depletion of resources, spatial and temporal fluctuation in food availability
- In general, **sustainability** in the context of sustainable development is defined by the World Commission on Environment and Development (1987) as:

  ‘*forms of progress that meet the needs of the present without compromising the ability of future generations to meet their needs*’.

8.1. General aspects cont...

Conceptually sustainability comprises environmental, economic, and social aspects



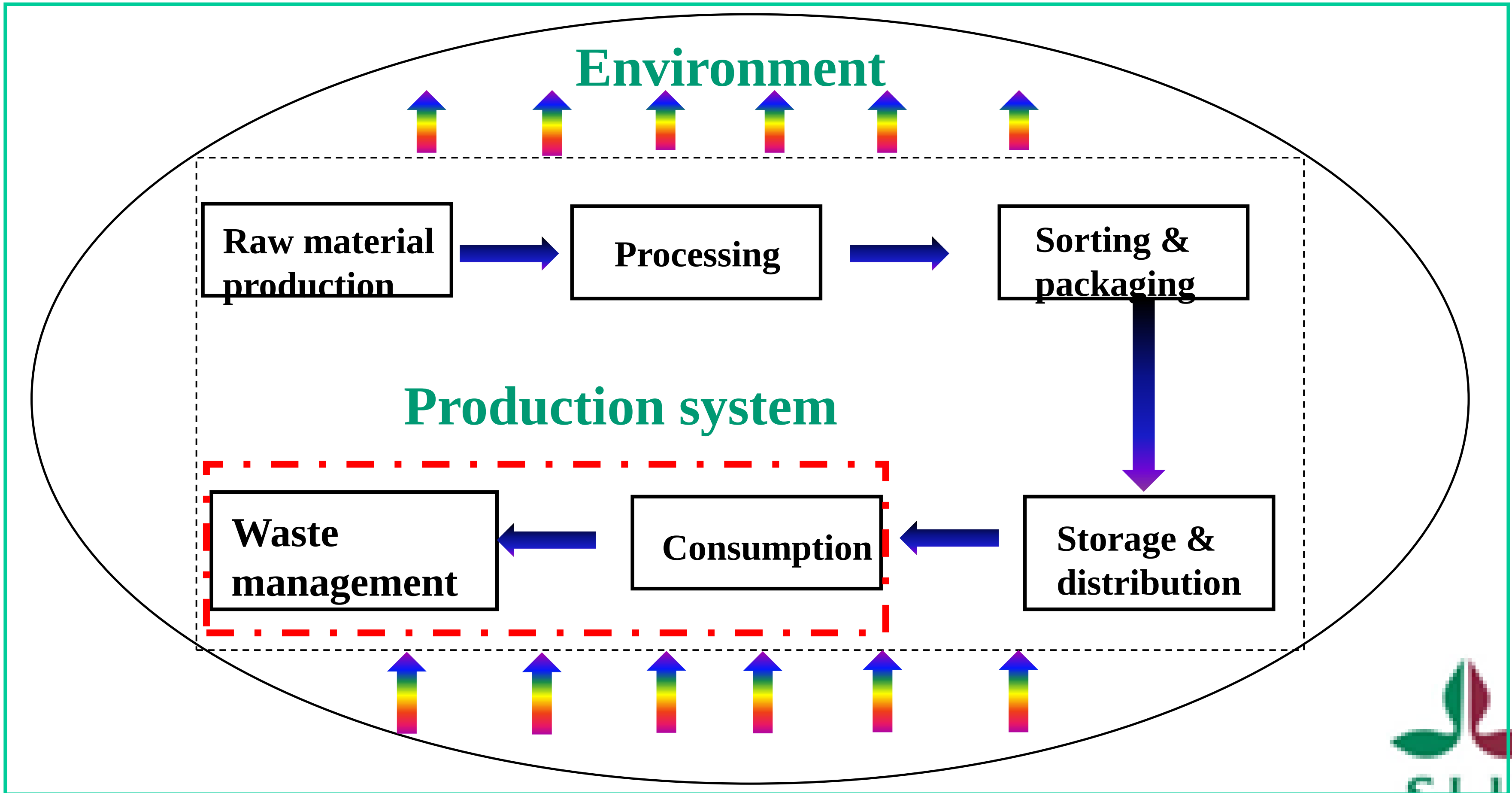
8.1. General aspects cont…

From sustainable food production and supply point of view:

- The **environmental dimension** considers environmental burden such as greenhouse gas (GHG) emissions, resource depletion, and damage on biodiversity etc
- **Economic dimension** considers business development related factors such as cost of food production and supply, profitability, and contribution to local economy.
- **Social aspect** addresses issues such food safety, food quality and consumer health, consumer satisfaction, societal food security, animal welfare and working environment for society involved in food sector.

8.1. General aspects cont...

Production system and environment



8.1. General aspects cont…

- Sustainability of food value chains must increases to feed the increasing and more urbanized world population.
- This requires to introduce more efficient food production and processing (e.g. drying), storing, and transporting techniques at regional or farm levels.
- It also worth to increase food production in more productive areas as self-sefficient community with less environmental and economic cost
- Such local food production should be integrated with organic food production to increase the environmental and social benefits

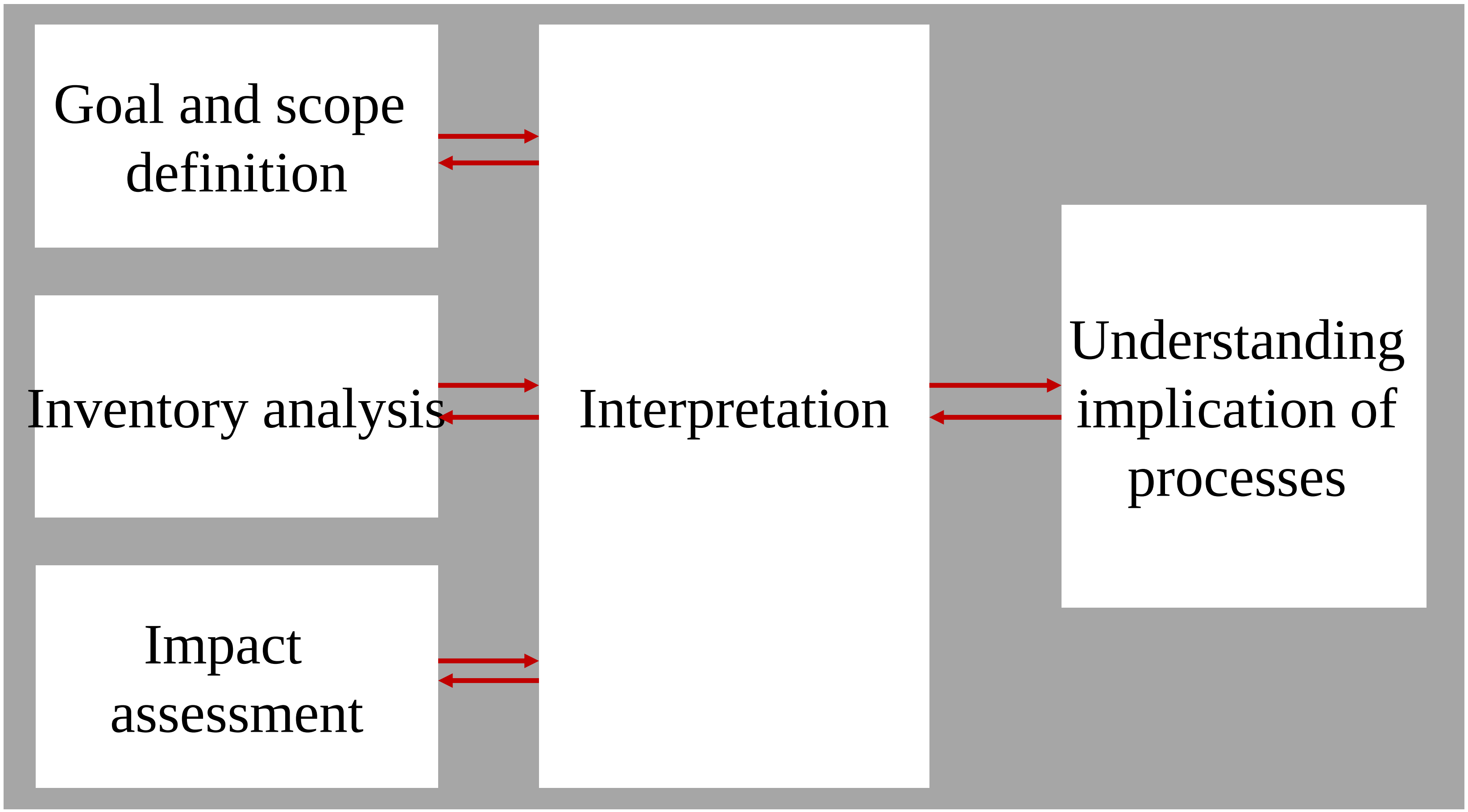
8.2. Environmental impacts of selected organic produces

Life cycle analysis (LCA) as a tool

- **Definition**: according to ISO 14040, LCA is the "compilation and evaluation of inputs, outputs and potential environmental impacts of a product system throughout its life cycle"
- to evaluate the environmental performance of a product (and service) considering its 'life-cycle stages'
- to promote eco-design i.e. designing more environmentally friendly products (e.g. by companies)
- to support decision making in complex business strategies or government policies
- To provide appropriate information to consumers (eg. via labeling) regarding environmental impact of a product or service

8.2. Environmental impacts cont…

LCA Framework

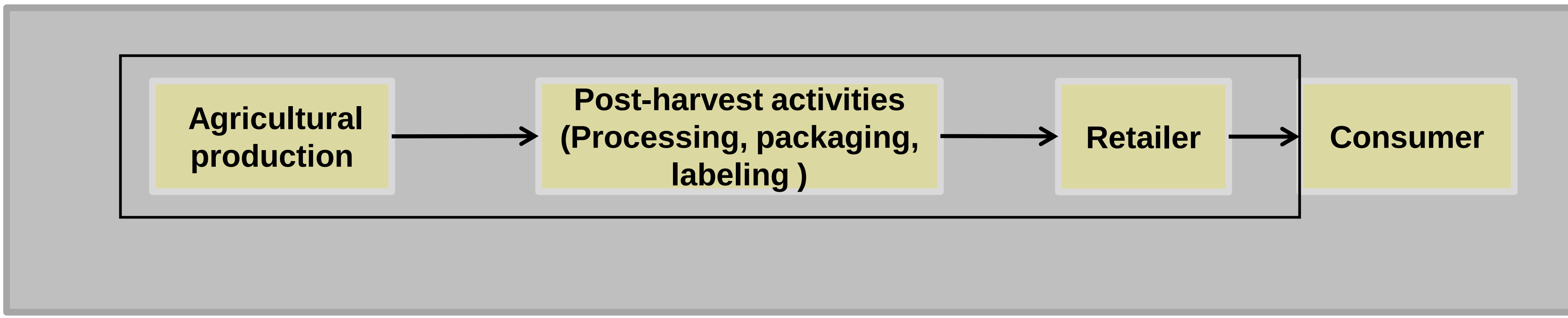


8.2. Environmental impacts cont...

- **Goal and Scope of LCA studies**
- **Goal:** to assess the environmental burdens of organic beef meat, apple fruit, carrot, tomato production and distribution in Sweden and organic salmon farmed in Norway
- **Questions to be answered:**
  - ❖ What is the environmental impact of selected organic food products produced in Sweden and that of organic salmon produced in Norway?
  - ❖ How supper-chilling and drying processes influences the environmental impacts?
  - ❖ What are the environmentally hot-spot stages of selected product life cycle?

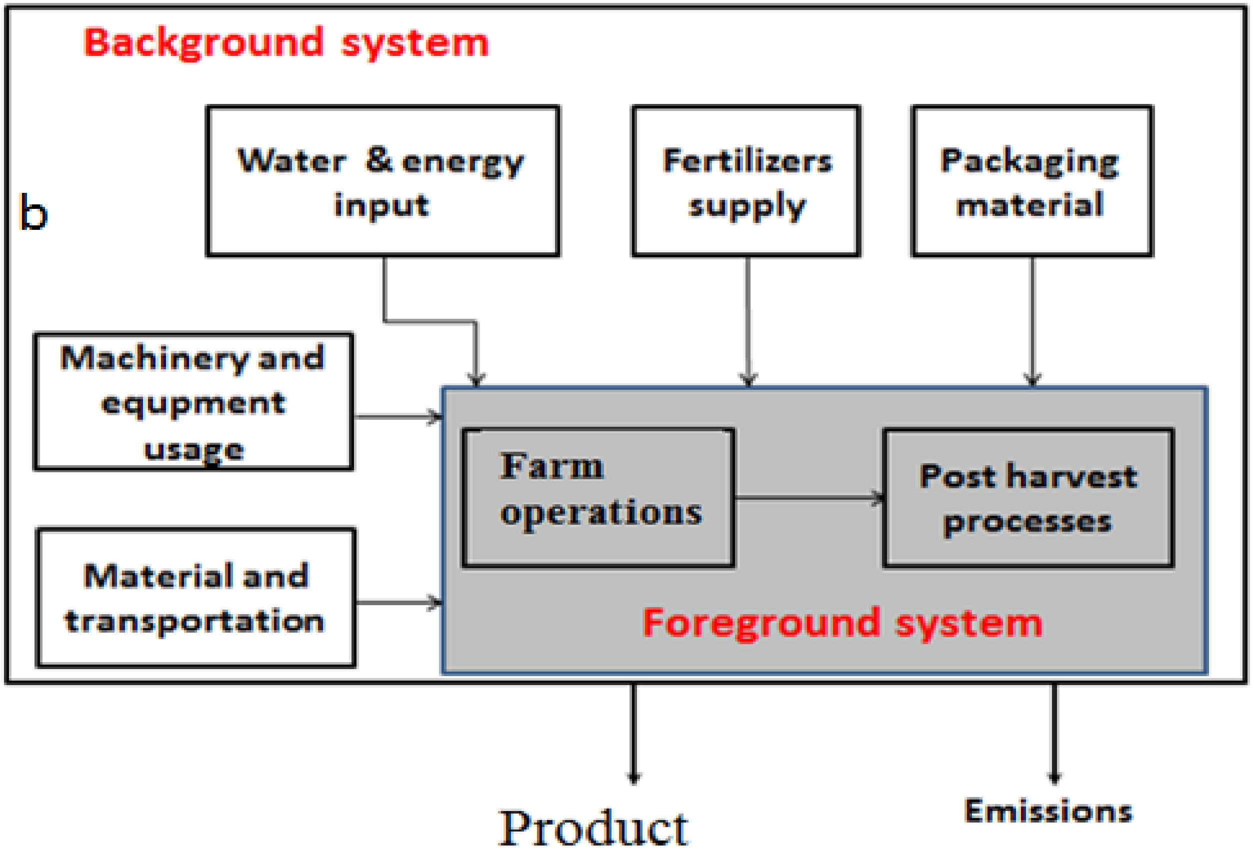
8.2. Environmental impacts cont...

- **System boundary and approach:**
  - ❖ The LCA follows the following product value chain



- **Impact categories are:**
  - ⇨ Major impact categories considered in this study:
    - ❖ **Energy demand in Cumulative Energy Demand (CED) form**
    - ❖ **Global warming: in kg CO2 equivalent**
- **Allocation principle: both mass allocation and economic allocation considered where appropriate**

8.2. Environmental impacts cont…



Simplified process flow chart

8.2. Environmental impacts cont...

Organic food description	Functional unit
salmon (cold chain supply system)	1 ton of fresh salmon fillet supplied to consumer
salmon (with supper chilling)	1 ton of supper-chilled salmon fillet supplied to consumer
Fresh beef meat (bon-free)	1 ton of fresh meat at farm gate that is ready to be supplied to consumer as fresh meat
Dried beef meat (bon-free)	1 ton of fresh meat at farm gate that is ready to be supplied to consumer as dried meat
Fresh Apple	1 ton of fresh apple at farm gate that is ready to be supplied to consumer as fresh apple
Dried Apple	1 ton of fresh apple at farm gate that is ready to be supplied to consumer as dried apple
Fresh carrot supply case	1 ton of fresh carrot at farm gate that is ready to be supplied to consumer as fresh apple
Dried carrot supply case	1 ton of fresh carrot at farm gate that is ready to be supplied to consumer as dried apple
Fresh tomato	1 ton of fresh tomato at farm gate that is ready to be supplied to consumer as fresh apple
Dried tomato	1 ton of fresh tomato at farm gate that is ready to be supplied to consumer as dried apple

8.2. Environmental impacts cont…

Farmed Salmon production stages

- **Feed production:** for smolt and growing salmon
- **Fertilization:** eggs will be produced and fertilized
- **Smolt feeding**: feeding baby fish in fresh water
- **Smoltification:** transferring baby) fish from freshwater to sea-going
- **Farming(on-growing):** Growing in net-pens in sea water
- **Harvesting and processing**: Salmon ready for slaughtering will be harvested

a b

8.2. Environmental impacts cont…

Description of transport segments considered in LCA of SusOrganic project

Organic food value chain	Segments of food transport
Organic salmon production & supply within Norway	About 580km from farm/slaughter house to distribution center in Oslo, and further distribution within 50km radius
Organic salmon (Supply to France)	About 580km from farm/slaughter house to distribution center in Oslo, and further transport to France i.e. about 1700 km road transport with truck, and 95km over sea transport with car ferry.
Organic beef production & supply in Sweden	10 km from farm to abattoir (animal transport), 50km from abattoir to retailer
Apple, carrot, and tomato production & supply within Sweden	80 km from farm to processing facility; 50 km from processing facility to retailer

8.2. Environmental impacts cont...

Distribution scenarios for salmon fillet

Scenario	Processed product	Destination
Scenario-1	Fillet (normal cold chain)	Norway
Scenario-2	Fillet (Supper-chilled)	Norway
Scenario-3	Fillet (normal cold chain)	Paris
Scenario-4	Fillet (Supper-chilled)	Paris

Considered moisture content at drying process

Produce	Initial MC	Final MC
Apple	82%	10%
Carrot	87%	12%
Tomato	93%	12%
Beef meat	74%	5%

8.2. Environmental impacts cont...

Data inventory includes

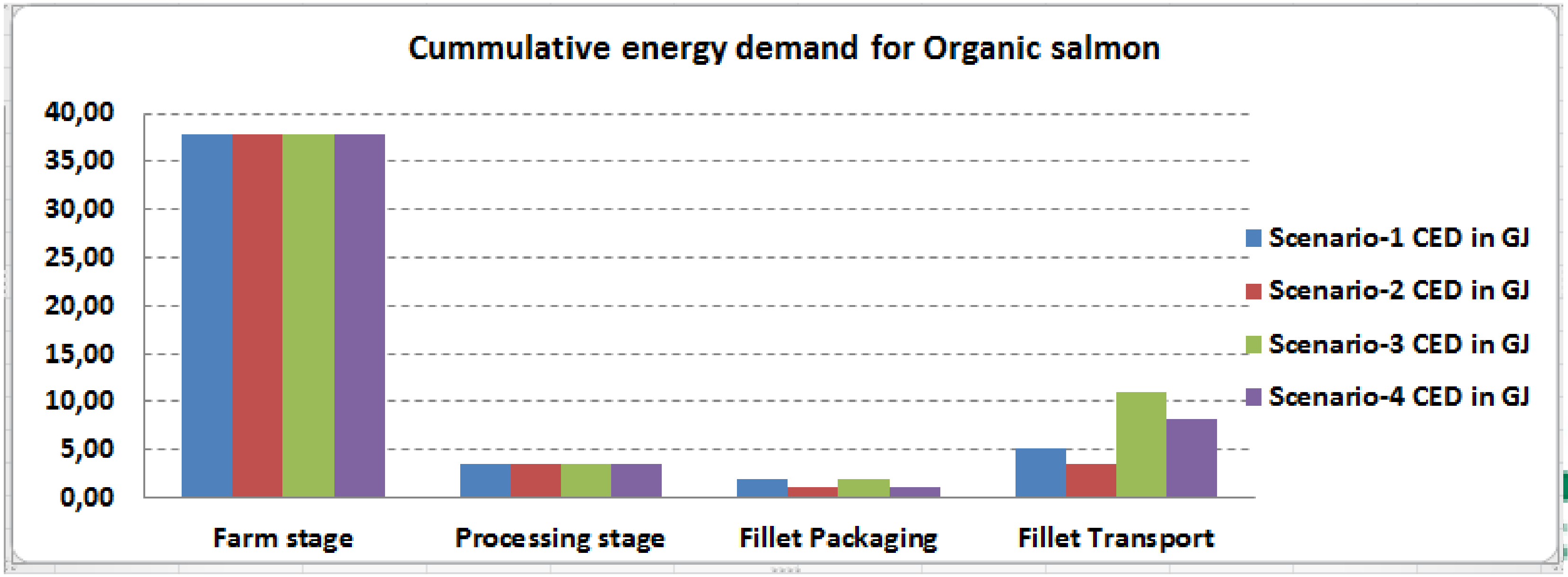
- Some primary data from organic farms, and experts of food processing
- From some pereviewed published papers
- From ecoinvent database and SimaPro LCA software

8.2. Environmental impacts cont...

Results of LCA of organic salmon

Scenario	Unit of CED	Total
Scenario-1	GJ	48,38
Scenario-2	GJ	46,06
Scenario-3	GJ	54,23
Scenario-4	GJ	50,71

Cummulative energy demand (CED)



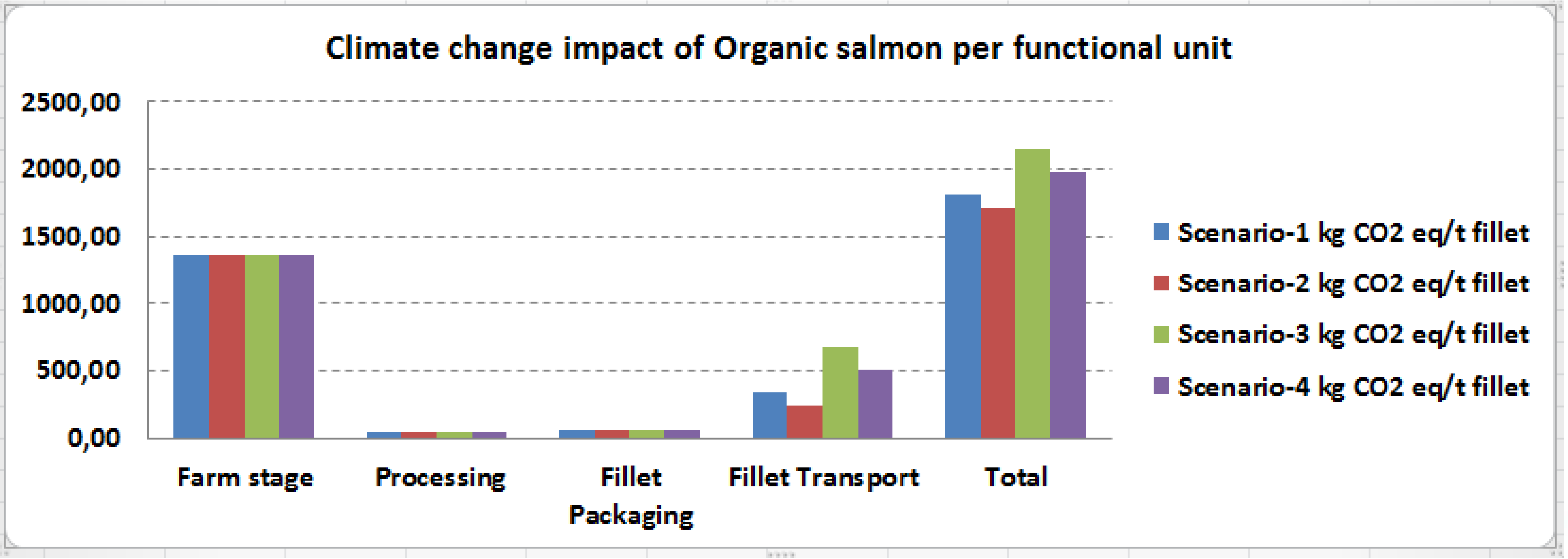
8.2. Environmental impacts cont...

- ❖ Due to supper-chilling, comparing Scenario-3 and Scenario-4, the CED is reduced by 6.5% overall with major contribution from transport related energy demand.
- ❖ Considering only packaging and transport stage, CED reduced by about 28%
- ❖ Feed production constitutes about 90% of CED at farm stage

- **Comparing scenario-3 and scenario-4:**
  - ❖ Supper-chilling reduced the share of climate change impact due to transport from 32% to 26%

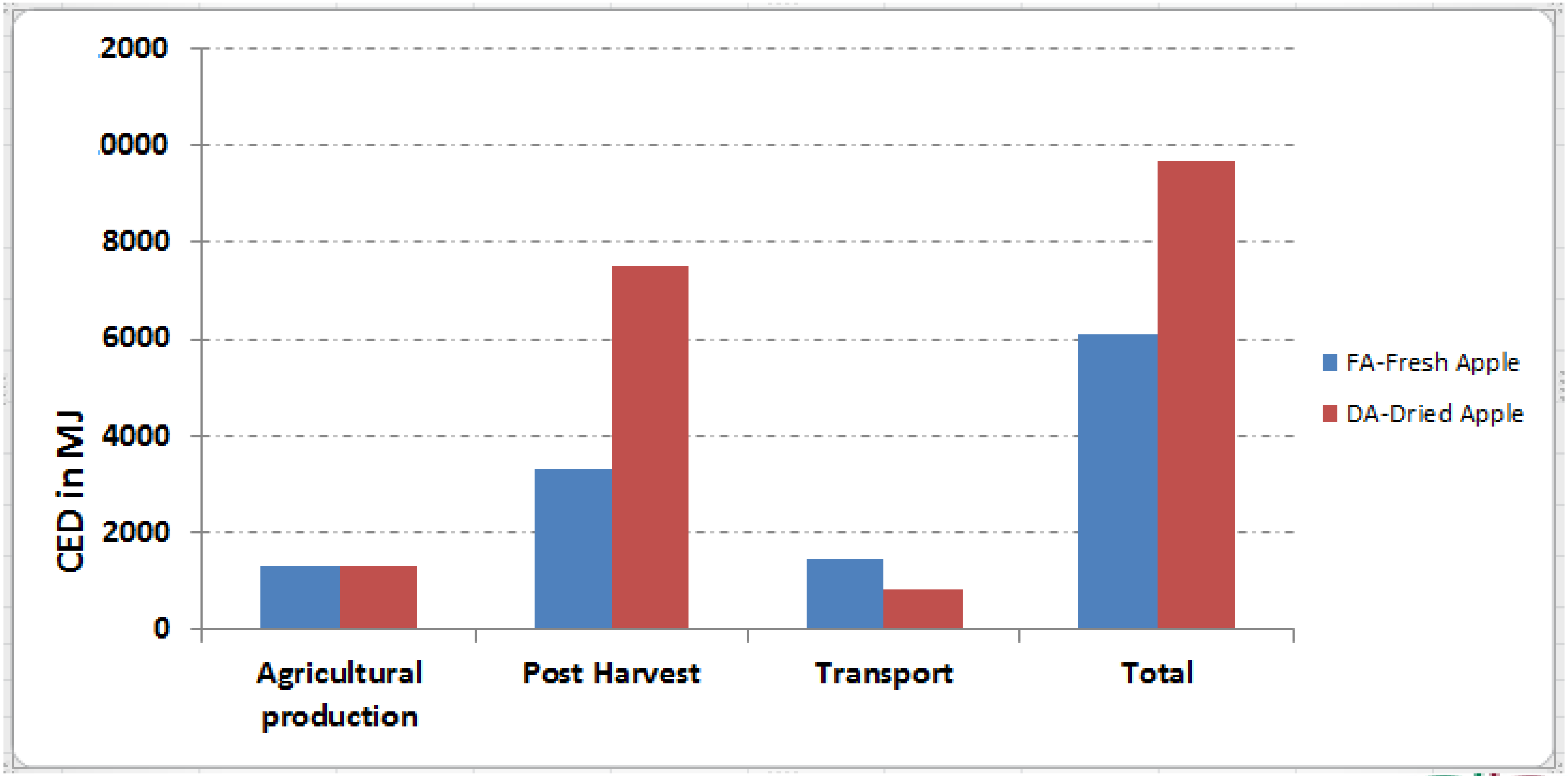
8.2. Environmental impacts cont...

- In Scenario-4 climate change impact is reduced by 7.8% when compared to scenario-3
- Supper-chilling positively influences the system from climate change impact point of view



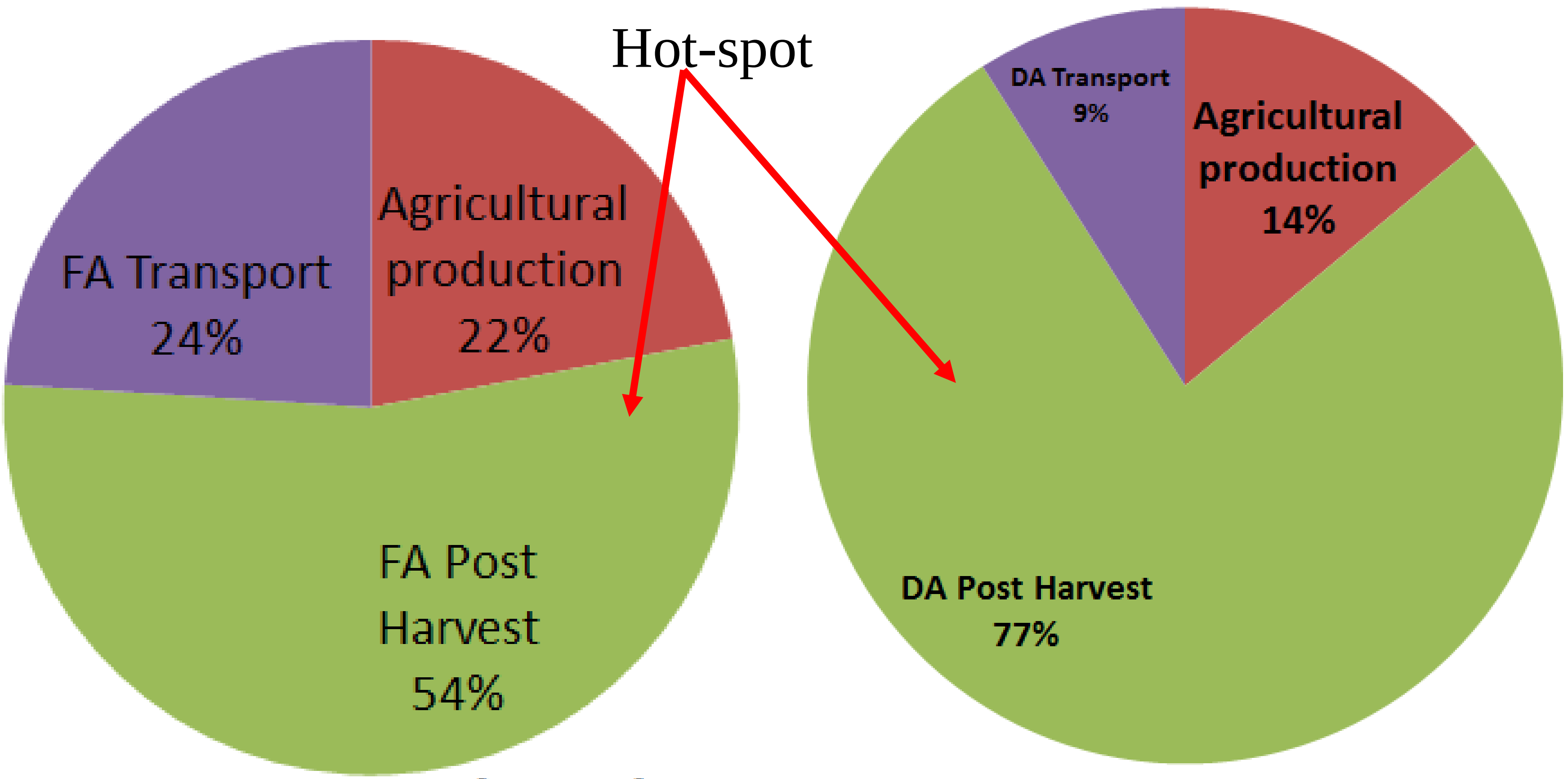
8.2. Environmental impacts cont...

Comparision of CED in apple



8.2. Environmental impacts cont...

Contribution (to total CED) of major life-cycle stages

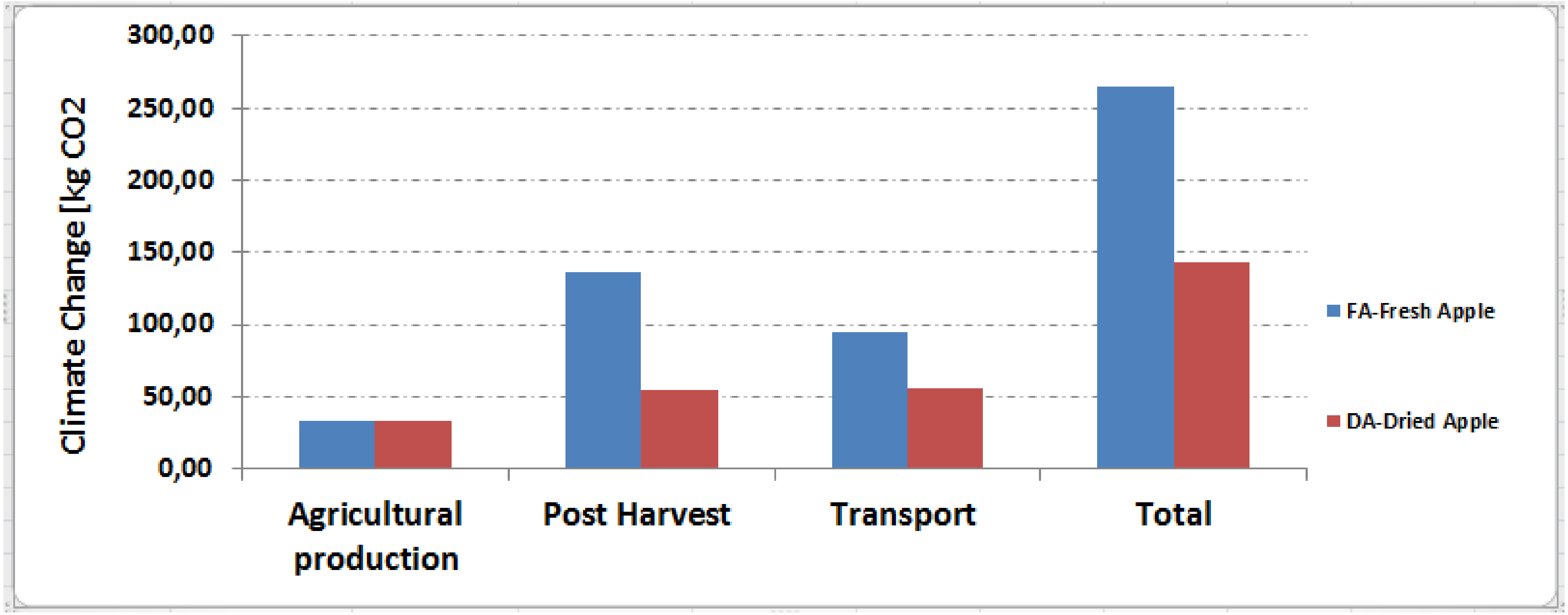


CED: FA-Fresh Apple

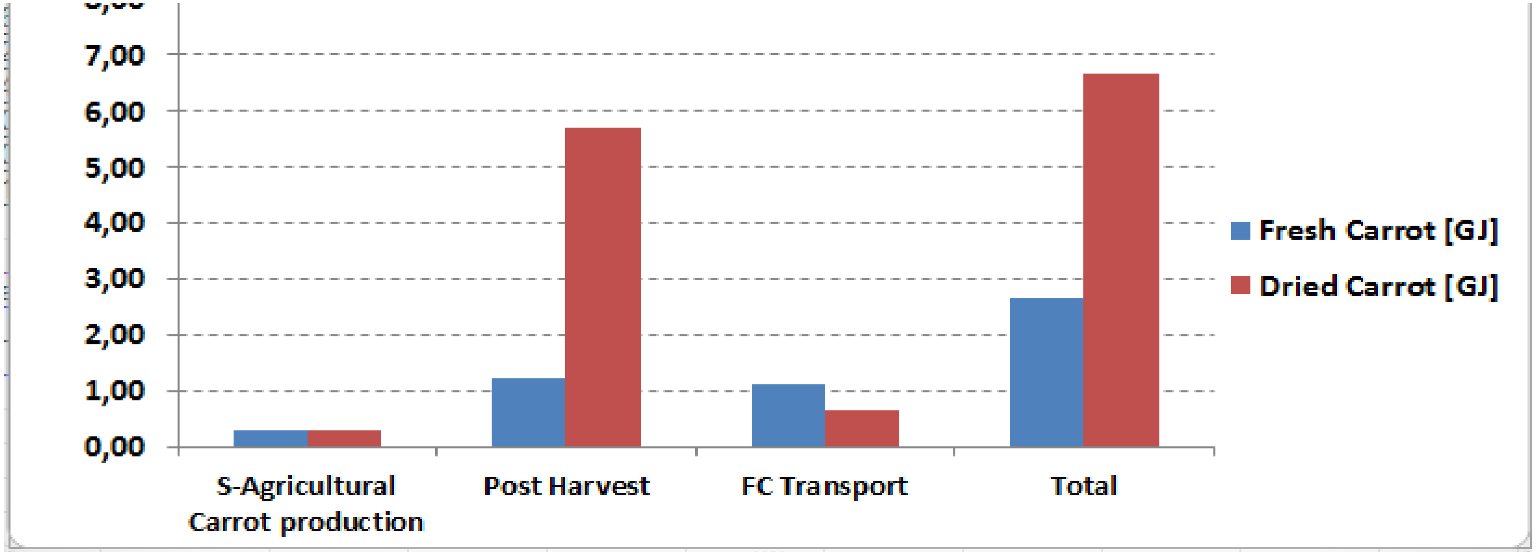
CED: DA-Dried Apple

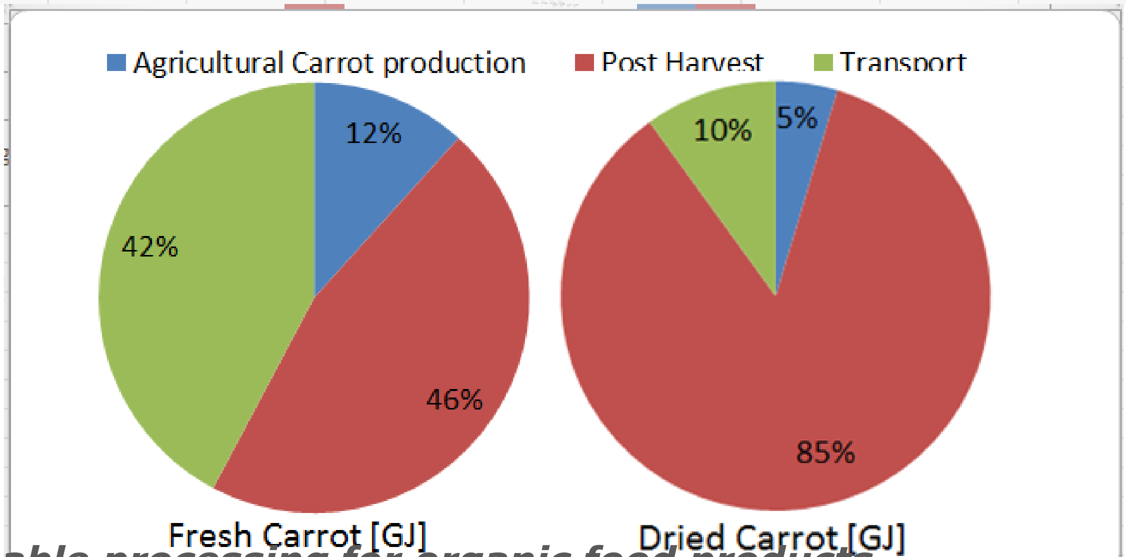
8.2. Environmental impacts cont...

Comparision of Climate change impact

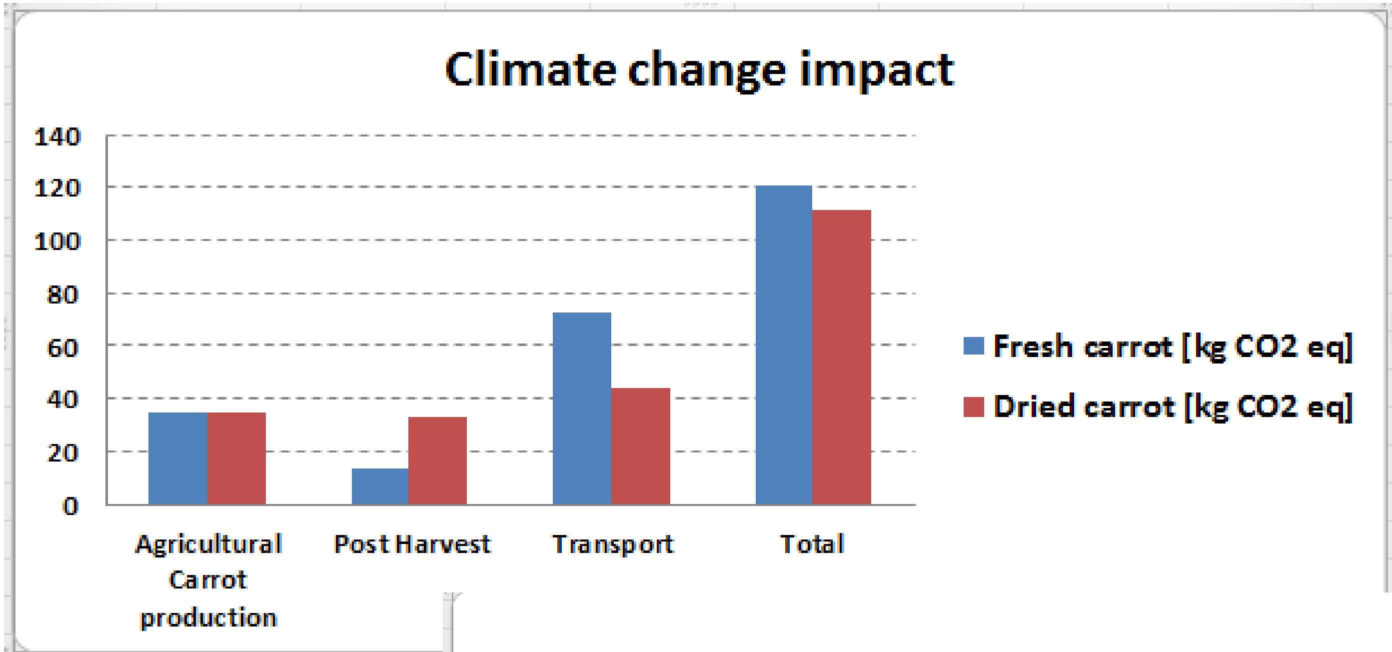


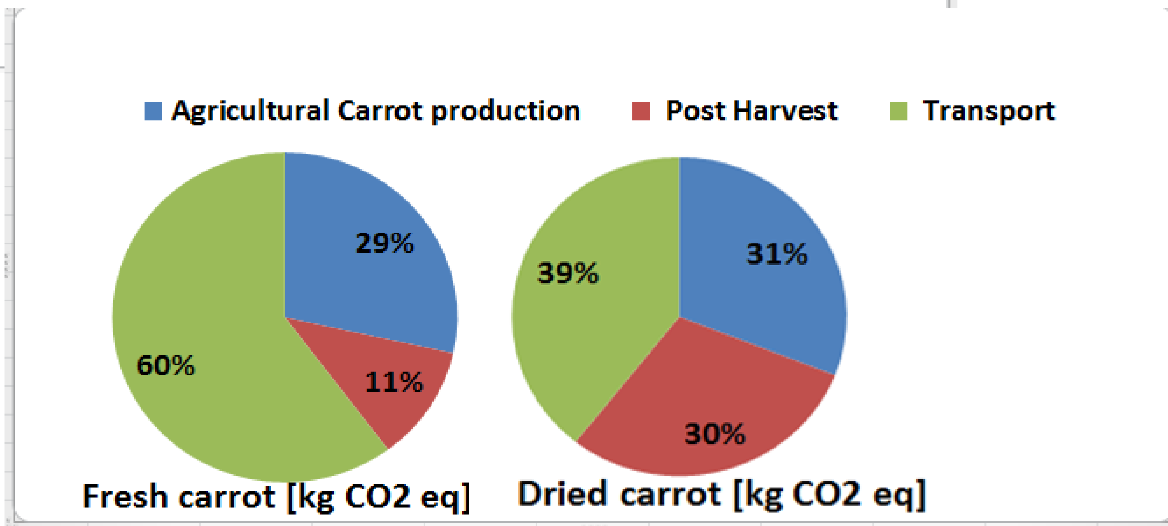
9.2. Environmental impacts cont…





8.2. Environmental impacts cont...





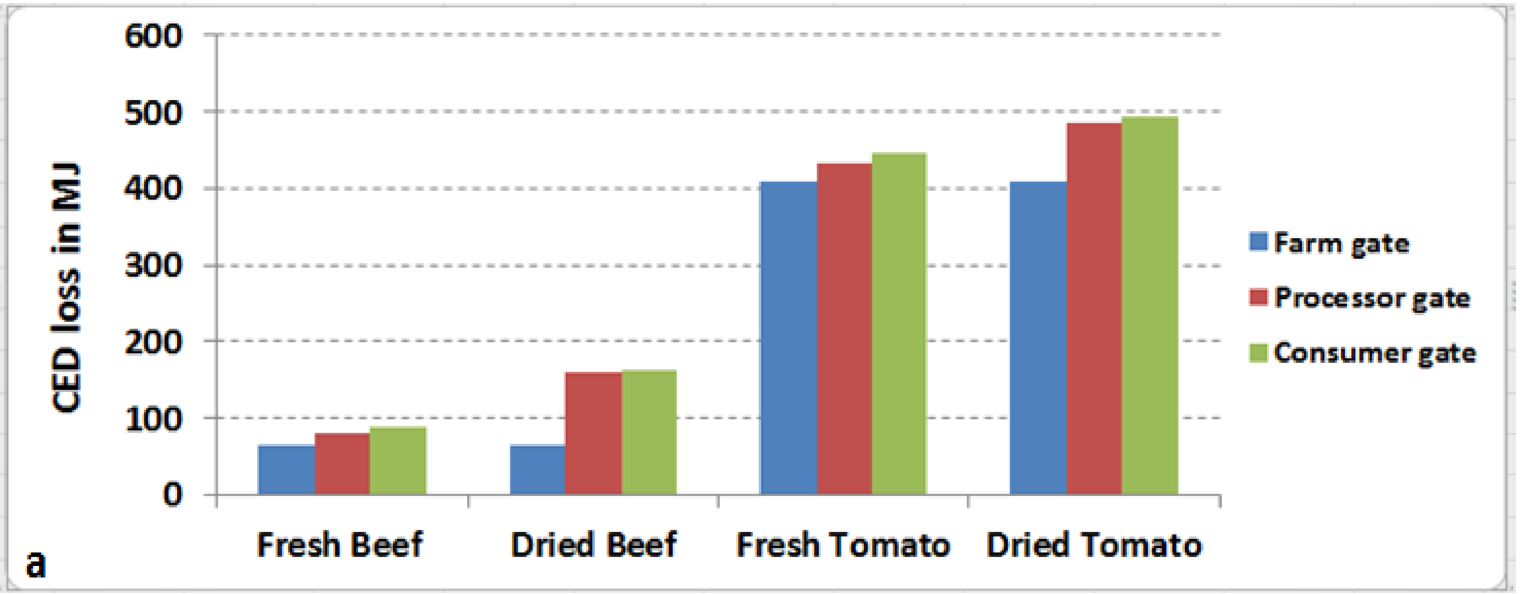
8.2. Environmental impacts cont…

- **Life cycle stages contribution to different impact categories per functional unit**

Value chain	Impact category	Unit	Agricultural production	Post-harvest processing	Transport	Total
Fresh beef meat	CED	GJ	6.34	1.7	0.69	8.72
	GWP_{100}	kg CO_2 eq	12 889	30	45	12 964
Dried beef meat	CED	GJ	6.34	9.72	0.27	16.33
	GWP_{100}	kg CO_2 eq	12 889	70	18	12 977
Fresh tomato	CED	GJ	41	2.17	1.42	44.58
	GWP_{100}	kg CO_2 eq	366	88	93	547
	CED	GJ	41	7.60	0.80	49.40
Dried tomato	GWP_{100}	kg CO_2 eq	366	49	52	467

8.2. Environmental impacts cont...

- The environmental impact due to food loss increases downstream of food supply chain. For instance, food loss equivalent to 10 kg of fresh product at farm level i.e. if the same amount (10 kg) is lost at different life cycle stages of beef and tomato, is presented here.



9.2. Environmental impacts cont…

Remarks

- Organic salmon and tomato value chains are most energy intensive.
- About 90% of the energy input at tomato farm stage is due to high energy for greenhouse heating and other on farm activities.
- Organic beef has highest GHG emission. Next to beef, organic salmon has high GHG emission value.
- The drying process reduced the total GHG emission in each product value chain. The reduction varies from 8% (case of organic carrot) to 46% (case of organic apple).

8.2. Environmental impacts cont...

- **In addition to improving energy efficiency at farm stage and post-harvest stages, introducing renewable energy is important where it is applicable, to improve the sustainability of organic food value chains.**
- **When implemented effectively, the drying process has multiple advantages from environmental point of view:**
  - i. **It increases product shelf life which in turn reduces product loss;**
  - ii. **It reduces the overall GHG emission due to reduction in packaging and transport volume; and**
  - iii. **The loss of dried product at consumer gate is associated with less GHG emission in comparison to equivalent loss of fresh tomato at consumer level.**
- **Food loss at downstream of the supply chain such consumer level is associated with more environmental burden, because, more resource inputs are used for processing, handling and transport.**

8.3. Economic aspects of selected organic produces

- **Economic drivers of sustainable food processing** can take a number of forms. It has been projected that world marketed energy consumption will grow by **53% between 2008 and 2035**. This, coupled with an expectation that energy prices will continue to increase in the long term.
- Selected unit operations in **food processing** facilities are particularly energy intensive, for example, **drying** and evaporation. It has been suggested that energy can account for up to **10% of the total production costs for products** requiring these unit operations.
- Between **30% and 50%** of incoming raw materials can end up as waste material during food processing.

8.3. Economic aspects cont…

- **Life cycle cost analysis (LCCA):**
  - ❖ LCCA is an **economic evaluation technique that** enables to determine the total cost of owning and operating a facility or a system over a given period of time.
  - ❖ Enables to provide additional information to supplment LCA based decision making
  - ❖ Help to identify the most cost-hot spot along product life cycle stages and take improvment actions
  - ❖ Can consider both investimate and operational costs
  - ❖ The same system boundary as case of LCA can be used
- Major costs considered in this study:
  - ❖ **Costs at Farm stage**
  - ❖ **Costs at post-harvest (processing, packaging etc)**
  - ❖ **Transport cost**

8.3. Economic aspects cont…

- **Cost can be determined at each life cycle stage:**

F= farm stage cost in € ;   H=post-harvest cost in €

T = transport cost in € ; TLC= total cost in €

$$TLC = F + H + T$$

8.3. Economic aspects cont…

LCCA results: contribution of each stage to total cost per functional unit

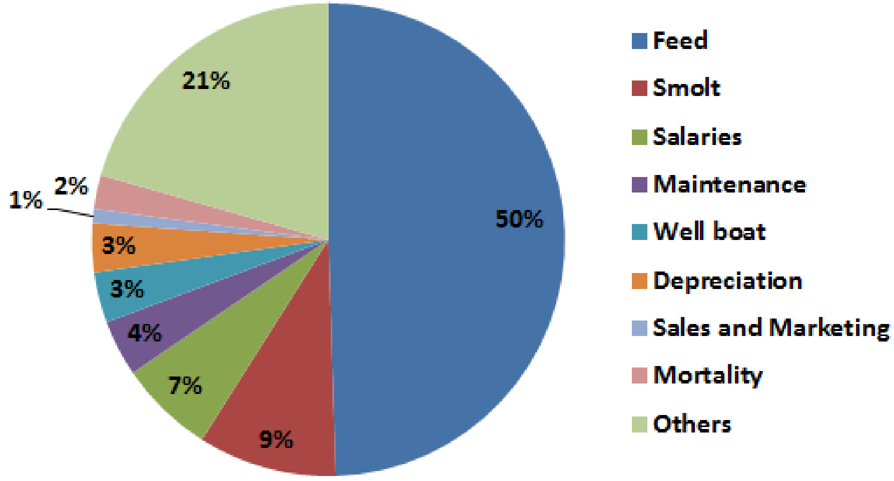
Organic food value chain	Unit[a]	Farm stage	Post-harvest processing stage	Transport stage	Total
Salmon supplied within Norway (with normal cold chain)	€	6213	475	27	6715
Salmon supplied within Norway (Supper-chilled)	€	6213	494	18	6725
Reduction/increase	*%*	*0*	*(+)4.0*	*(-)33.33*	*(+)0.15*
Salmon supplied to France (with normal cold chain)	€	6213	475	106	6794
Salmon supplied to France (supper-chilled)	€	6213	494	71	6778
Reduction/increase	*%*	*0*	*(+)4*	*(-)33*	*(-)0.24*
Fresh apple	€	1865	482	42	2391
Dried apple	€	1865	643	27	2537
Reduction/increase	*%*	*0*	*(+)33.4*	*(-)36*	*(+)6*
Fresh beef meat	€	6326	14204[b]	1550	22080
Dried beef meat	€	6326	14752[b]	885	21964
Reduction/increase	*%*	*0*	*(+)4*	*(-)43*	*(-)0.5*

[a]-The values are given per functional unit but not per tonne of final product; [b]- Estimated based on average 4.4% operating margin at processing and retail levels which could be higher in some cases

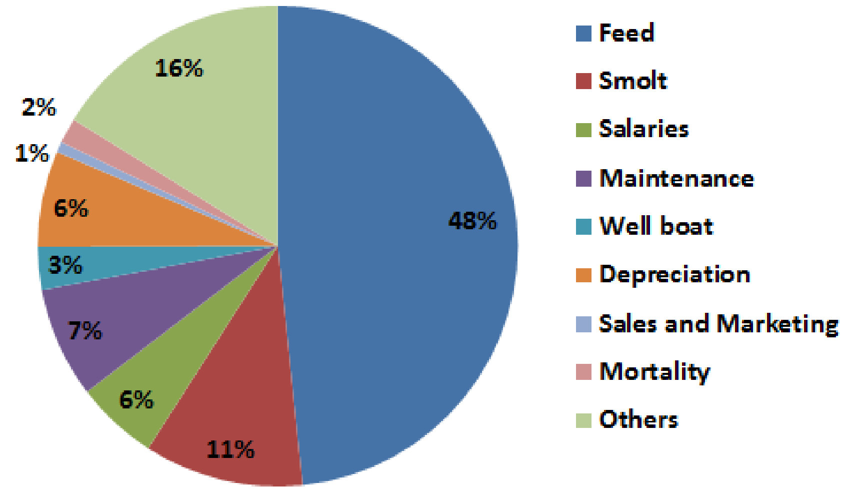
8.3. Economic aspects cont…

- The salmon farm stage is hot-spot with about 48% share of cost.
- Total cost at farm stage is about 6750 €/t fillet for organic salmon while it is about 4958 €/t for conventioal farmed salmon

Cost distribution for conventional farmed salmon production



Cost distribution for farmed organic salmon production



8.3. Economic aspects cont…

Remarks

- The supper-chilling process reduces the transport cost by about 33%. However, salmon farming stage and processing (including packaging) stages constitute about 92% and 7% of total life cycle cost respectively, and more improvement effort at these stages could improve the sustainability of organic salmon.
- In the case of longer distribution distance, food drying increases cost advantage when compared to the case of fresh product supply .

8.3. Economic aspects cont…

- At farm level the organic beef production cost is estimated to be higher than selling price of slaughter animals compromising the sustainability of organic beef production
- In general, the drying process increases the costs at processing stage, but it can be traded off by decreased volume of product and packaging to be transported.
- Introducing appropriate drying methods and packaging plays useful role in increasing food availability and reducing environmental and economic constraints.

References

- UN (2017). The Sustainable Development Goals Report 2017 of United Nations. URL: https://unstats.un.org/sdgs/files/report/2017/TheSustainableDevelopmentGoalsReport2017.pdf.
- LCA handbook (2004). Handbook on Life Cycle Assessment Operational Guide to the ISO Standards. Kluwer Academic Publishers; eBook ISBN: 0-306-48055-7; New York, Boston, Dordrecht, London, Moscow.
- Farr J.V. (2011). Systems Life Cycle Costing Economic Analysis, Estimation, and Management. Taylor & Francis Group, 6000 Broken Sound Parkway NW, Suite 300, Boca Raton, FL 33487-2742.
- Winther U., Ziegler F., Hognes E.S., Emanuelsson A., Sund V., and Ellingsen H. (2009). Carbon footprint and energy use of Norwegian seafood products. Research report; SINTEF Fisheries and Aquaculture.
- Schaub & Leonard, 1996. Composting: An alternative waste management option for food processing industries. Trends in Food Science & Technology 7(8):263-268.

References

- Borg J., Per Fors, Simon Isaksson S., Kambanou M.L.(2016). Food transport within the context of sustainability. Sustainability Opportunities 2016. https://gmv.gu.se/_digitalAssets/1593/1593132_final-presentation-transportation-of-food.pdf
- Corrado S., Ardente F., Sala S., Saouter E. (2016). Modelling of food loss within life cycle assessment: From current practice towards a systematization. Journal of Cleaner Production, 140 (2017) 847-859. http://dx.doi.org/10.1016/j.jclepro.2016.06.050.
- Pelletier N. and Tyedmers P. (2007). Feeding farmed salmon: Is organic better? Aquaculture 272: 399-416. Doi:10.1016/j.aquaculture.2007.06.024.
- Alberto Ramírez (2007). Salmon by-product proteins. FAO, Rome. http://www.fao.org/3/a-a1394e.pdf accessed on 27-04-2017.
- EIA, 2011: International energy outlook 2011. **https://www.eia.gov/outlooks/archive/ieo11/pdf/0484(2011).pdf**