UNIVERSITÀ DEGLI STUDI DI TORINO
ALMA UNIVERSITAS TAURINENSIS

DISAFA - Department of Agriculture , Forestry and Food Science

IRIS – Intedisciplinary Research Institute of Sustainability

Eating City Summer Campus
The impact of our daily food system into the 4 natural elements.
La Bergerie de Villarceaux
France – 12-22 August 2015

Energy assessment in food systems

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Ecological Footprint

Quantifies the biocapacity needed to support a population.

Global hectares

Carbon Footprint

Quantifies climate change potentials during the production of a good.

kg CO_2-equivalent

Water Footprint

Quantifies the real and virtual water needed to produce a good.

m^3 of blue, green and gray water

Energy Footprint

???

Structure of the lecture

Overview of energy use in the European food sector

Methods for assessing energy use and efficiency

Energy in the food supply chain

Sustainability from a thermodinamic point of view

Overview of energy use in the European food sector

A new report launched by the European Commission's Joint Research Centre (JRC) at EXPO Milano.

https://ec.europa.eu/energy/en/news/sustainable-energy-use-eu-food-sector


European Commission

JRC SCIENCE AND POLICY REPORT

Energy use in the EU food sector: State of play and opportunities for improvement

F. Monforti-Ferrario, J.-F. Dallemand, I. Pinedo Pascua, V. Motola, M. Banja, N. Scarlat, H. Medarac, L. Castellazzi, N. Labanca, P. Bertoldi

D. Pennington, M. Goralczyk, E. M. Schau, E. Saouter, S. Sala

B. Notarnicola, G. Tassielli, P. Renzulli.

Edited by F. Monforti-Ferrario and I. Pinedo Pascua

2015

Joint Research Centre

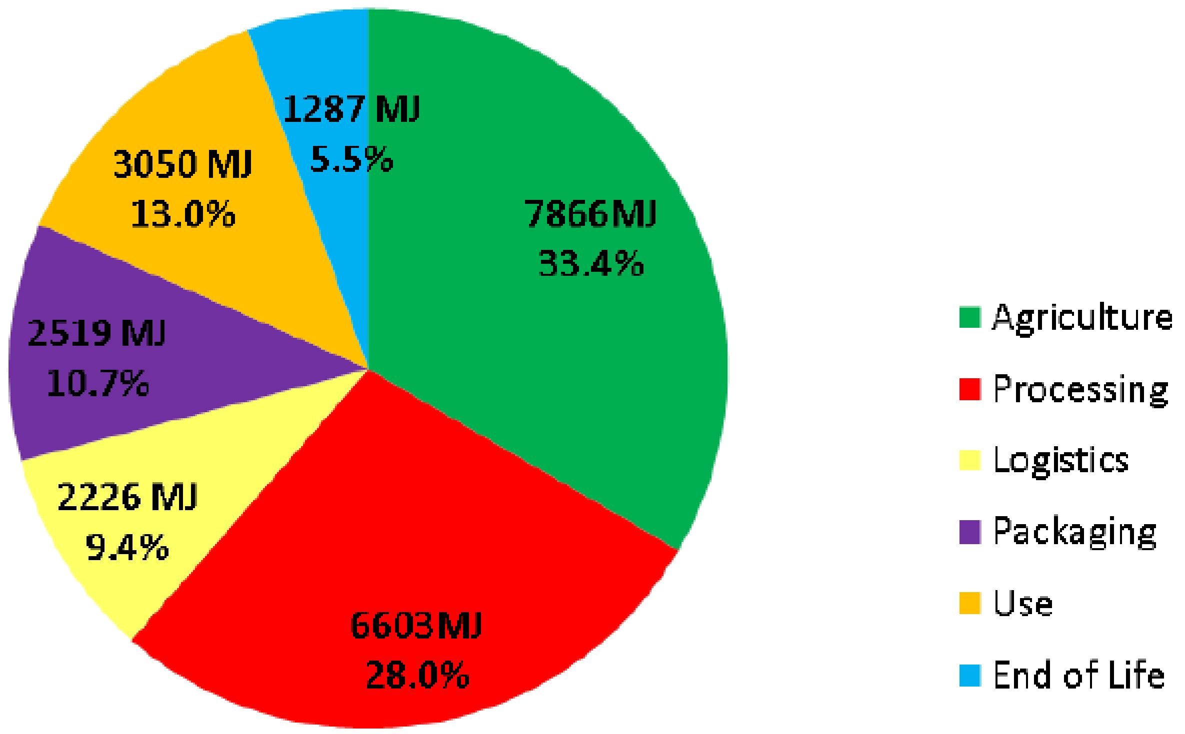
Report EUR 27247 EN

Introduction

The food sector is a major consumer of energy: the amount of energy necessary to cultivate, process, pack and bring the food to European citizens' tables accounts for **26% of the EU's final energy consumption in 2013**.

European Commission, 2015. Energy use in the EU food sector: State of play and opportunities for improvement. Report EUR 27247 EN, Joint Research Centre, DOI: 10.2790/158316

Energy breakdown in the sector



Energy embedded in the food consumed by the average EU-27 citizen, broken down by food production step.

European Commission, 2015. Energy use in the EU food sector: State of play and opportunities for improvement. Report EUR 27247 EN, Joint Research Centre, DOI: 10.2790/158316

Energy breakdown in the sector

While the "end of life" phase including final **disposal of food waste** represents only slightly more than **5%** of total energy use in the EU food system, food waste actually occurs at every step of the food chain.

In 2014 the EU generated 100 million tonnes of food waste, primarily at the household level and manufacturing. Given the large amounts of energy involved in food production, reducing food waste is an important vector for improving the overall energy efficiency of the food system.

Food waste also has the potential to play a role in renewable energy production as a feedstock for bioenergy production.

European Commission, 2015. Energy use in the EU food sector: State of play and opportunities for improvement. Report EUR 27247 EN, Joint Research Centre, DOI: 10.2790/158316

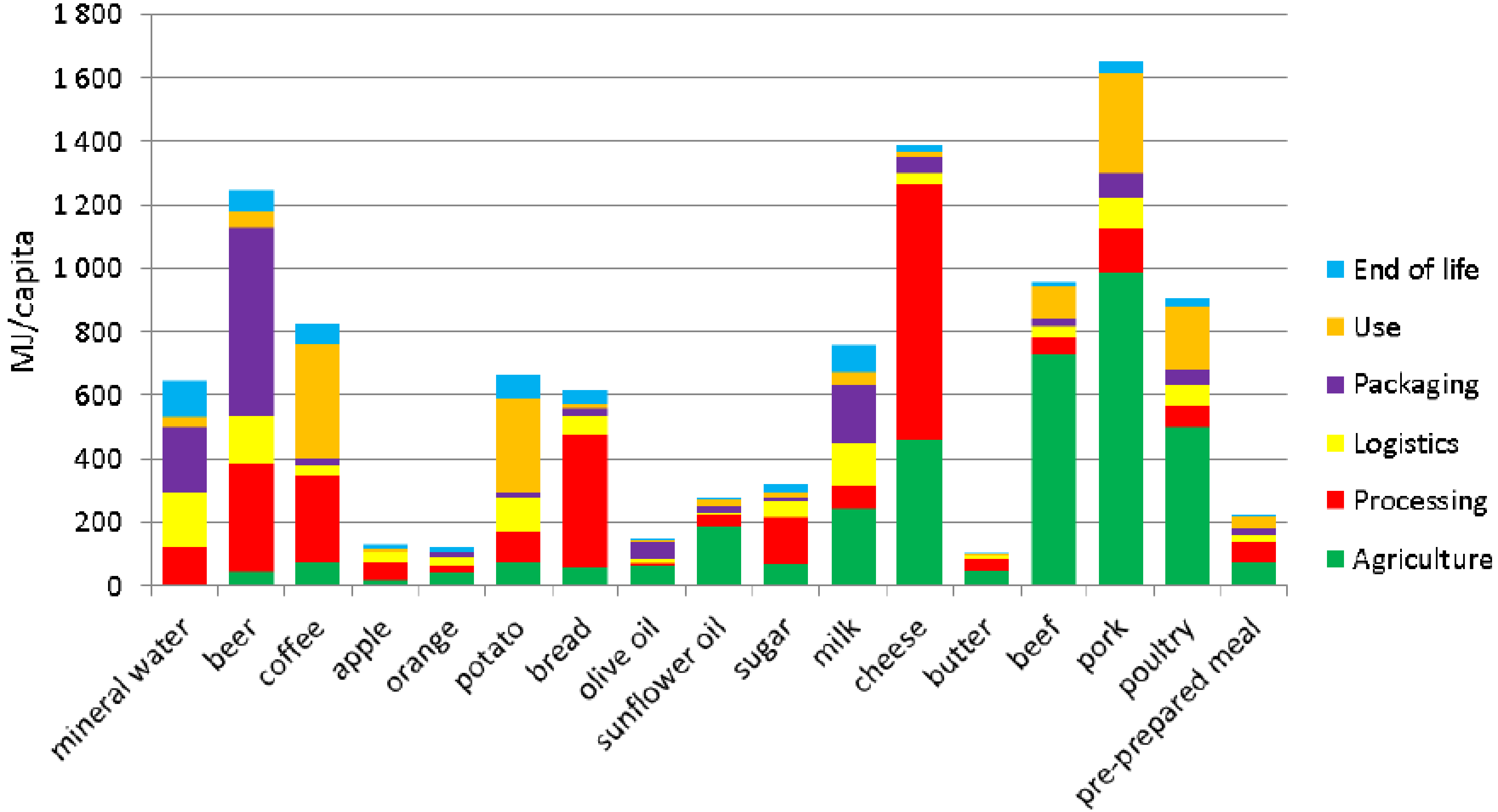
Energy in food

Different food products need very different amounts of energy per unit of mass depending on their nature, their origin and the kind of processing they have been subjected to.

Refined products and products of animal origin generally need an amount of energy several times larger than vegetables, fruits and cereal products.

European Commission, 2015. Energy use in the EU food sector: State of play and opportunities for improvement. Report EUR 27247 EN, Joint Research Centre, DOI: 10.2790/158316

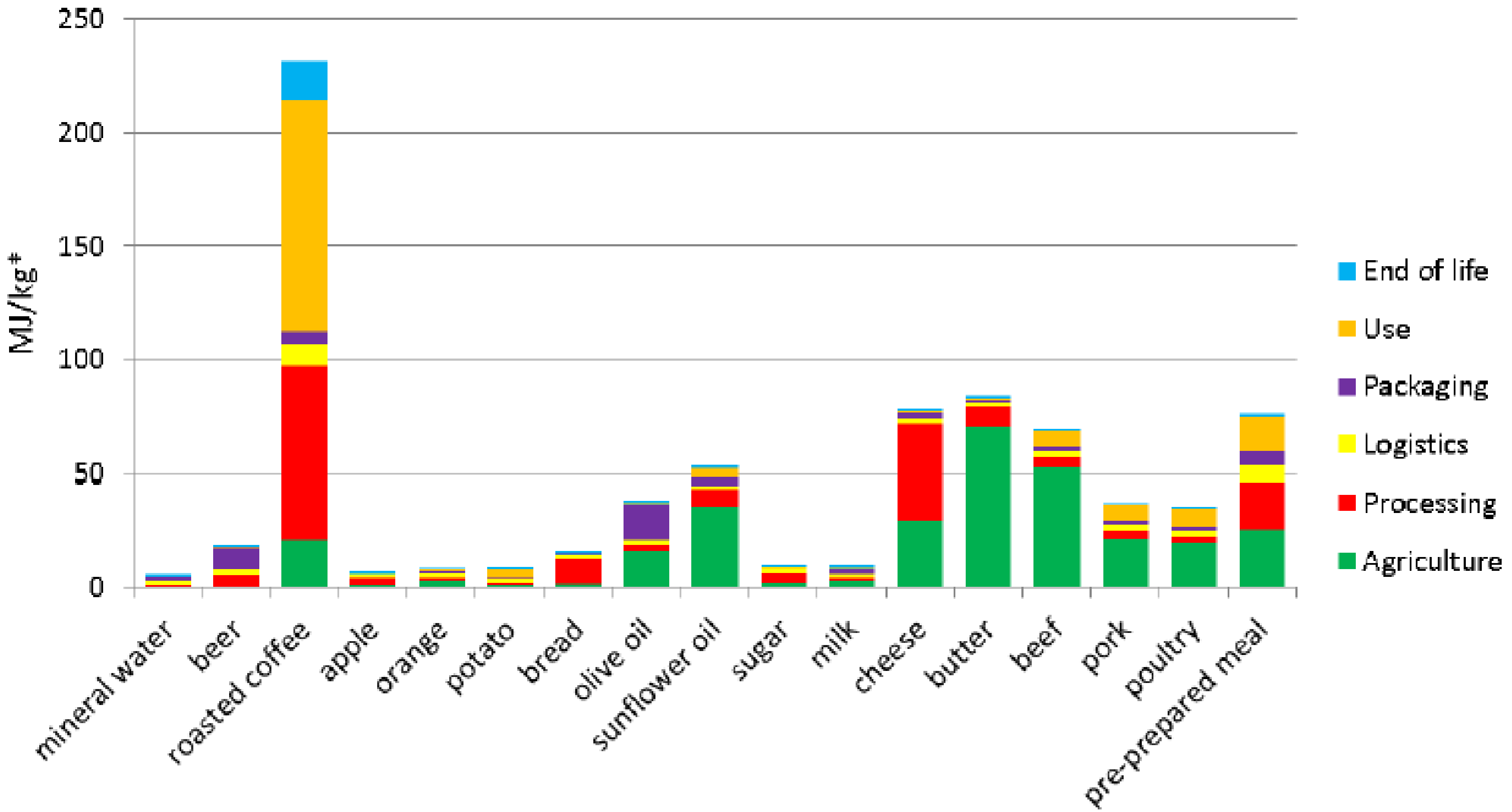
Energy in food



Energy embedded in the JRC food consumption basket for the average citizen, broken down for products and production steps. Units: MJ/capita.

European Commission, 2015. Energy use in the EU food sector: State of play and opportunities for improvement. Report EUR 27247 EN, Joint Research Centre, DOI: 10.2790/158316

Energy in food

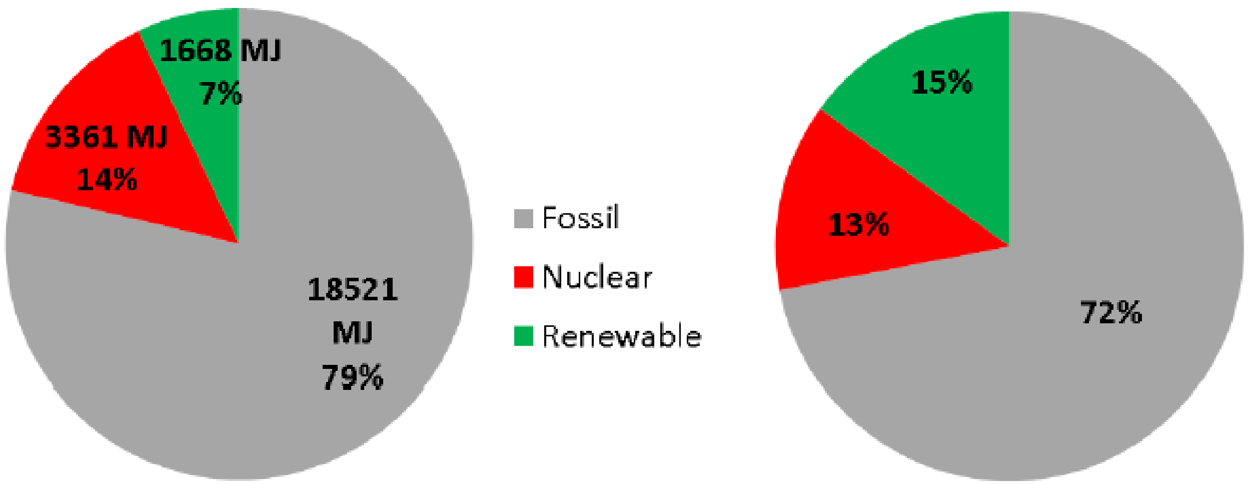


Energy embedded in the production steps and products making up the JRC food basket. *Units in MJ/kg or MJ/l (for beer, milk and mineral water).

European Commission, 2015. Energy use in the EU food sector: State of play and opportunities for improvement. Report EUR 27247 EN, Joint Research Centre, DOI: 10.2790/158316

Renewable energy in the sector

While the EU has made important progress in incorporating renewable energy across the economy, the share of renewables in the food system remains relatively small.

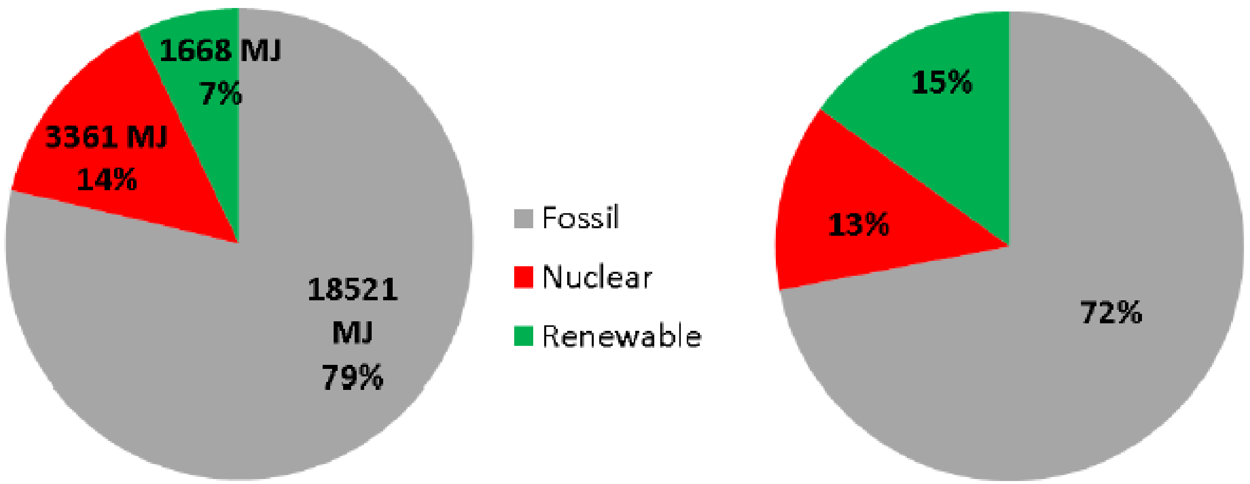


Energy embedded in the food consumed by the average EU-27 citizen in 2013, detailed per energy source (left) compared to the overall EU-27 energy consumption mix in 2013 (right)

European Commission, 2015. Energy use in the EU food sector: State of play and opportunities for improvement. Report EUR 27247 EN, Joint Research Centre, DOI: 10.2790/158316

Renewable energy in the sector

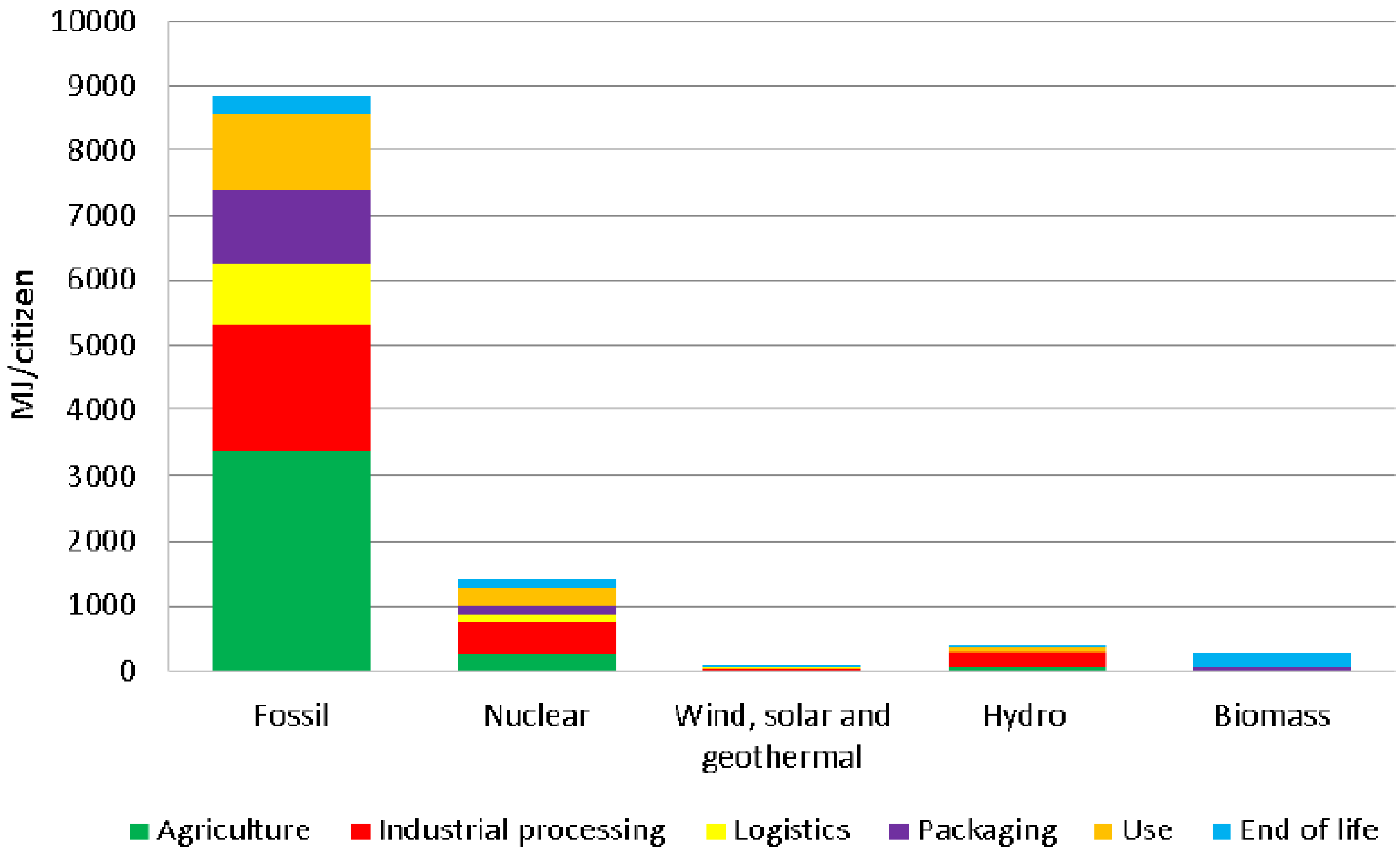
The relatively low share of renewables in the food sector is also linked to the fact that about one fifth of food consumed in the EU is imported from regions outside the EU where the renewable share is generally lower than 15%.



Energy embedded in the food consumed by the average EU-27 citizen in 2013, detailed per energy source (left) compared to the overall EU-27 energy consumption mix in 2013 (right)

European Commission, 2015. Energy use in the EU food sector: State of play and opportunities for improvement. Report EUR 27247 EN, Joint Research Centre, DOI: 10.2790/158316

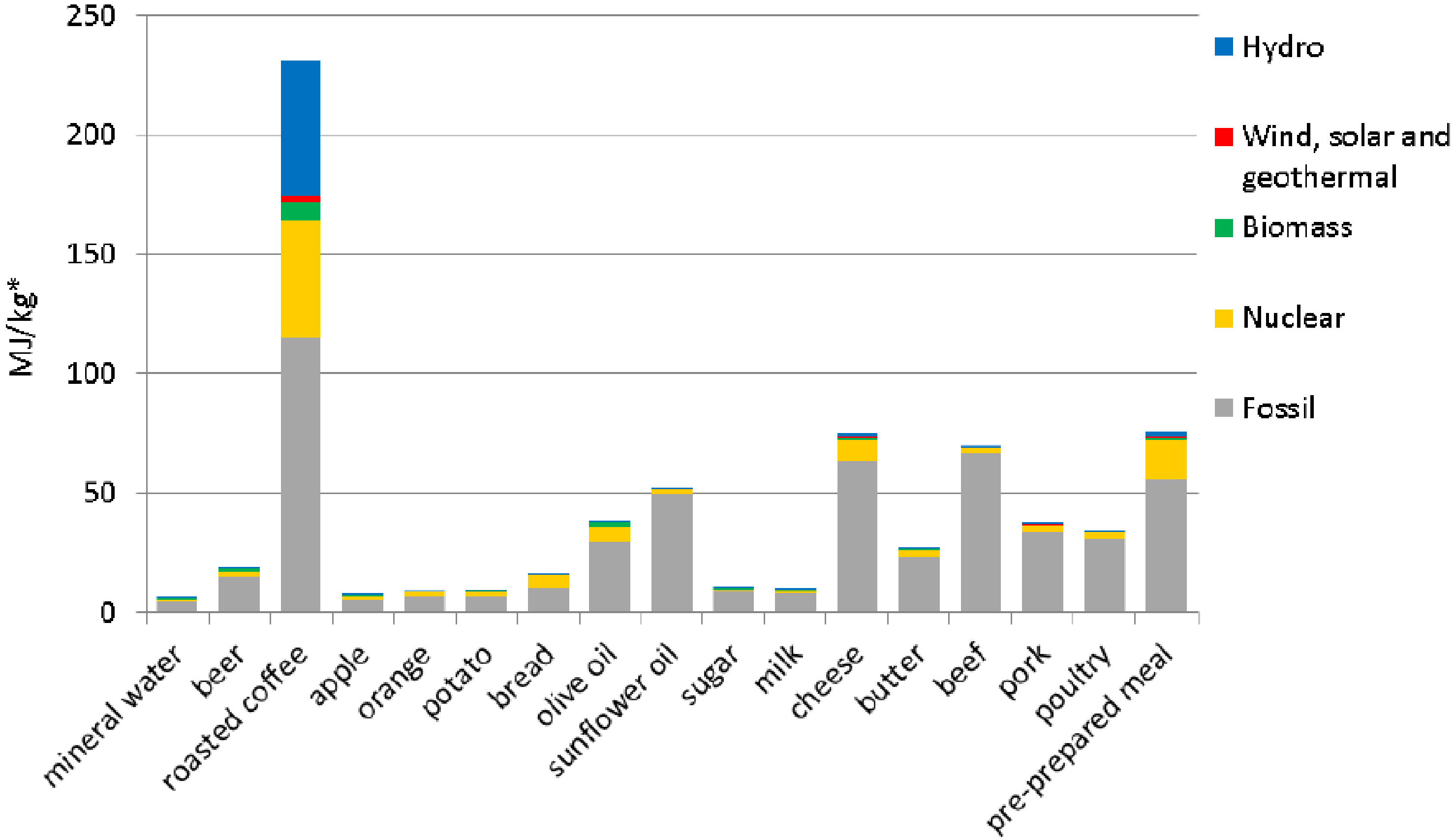
Renewable energy in the sector



Sources of energy embedded in the JRC food basket in units of mega joules (MJ) in absolute terms. Units: MJ/capita.

European Commission, 2015. Energy use in the EU food sector: State of play and opportunities for improvement. Report EUR 27247 EN, Joint Research Centre, DOI: 10.2790/158316

Renewable energy in the sector



Sources of energy embedded in each of the products making up the JRC food basket in absolute terms.
****Units in MJ/kg or MJ/l (for beer, milk and mineral water).***

European Commission, 2015. Energy use in the EU food sector: State of play and opportunities for improvement. Report EUR 27247 EN, Joint Research Centre, DOI: 10.2790/158316

Renewable energy in the sector

Renewable energy can substitute fossil fuels, partially or completely, in several food production steps, improving sustainability and contributing to decoupling the food costs from the oil price.

Thanks to Renewable Energy Directive targets the amount of RE in the food production in Europe will grow. On top of that, farmers and companies can directly buy RE from a specific 'green' energy supplier or even self-produce their energy, e.g. through biogas production plants or combined heat and power units fed with agriculture residues.

European Commission, 2015. Energy use in the EU food sector: State of play and opportunities for improvement. Report EUR 27247 EN, Joint Research Centre, DOI: 10.2790/158316

Methods for assessing energy use and efficiency

RESOURCE CONSUMPTION BASED INDICATORS

Environmental space (Opshoor, 1995)

Ecological Footprint

(Rees, Wackernagel, 1996)

Water footprint

NPP (Vitousek, 1986)

HANPP (IFF Austria)

METABOLISM BASED INDICATORS

Material Flow Analysis

Wuppertal Institut, IFF, 2000

eMergy (Odum, 1996)

exergy (Jorgensen,1998)

Energy Flow Analysis (IFF)

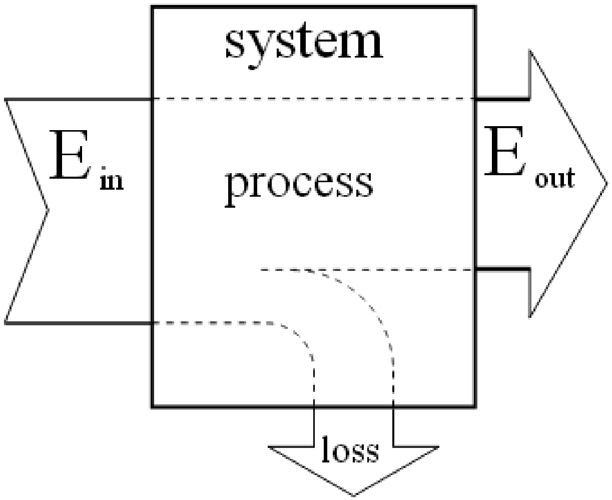
ENVIRONMENTAL IMPACT BASED INDICATORS

Life Cycle Assessment

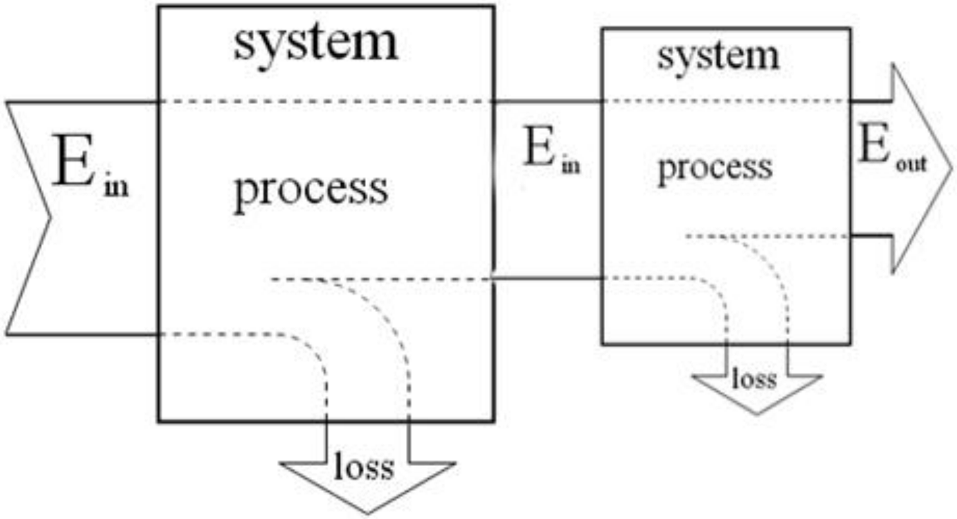
Carbon footprint

"If all you have is a hammer, everything looks like a nail"
Abraham Maslow

EMergy analysis in food systems

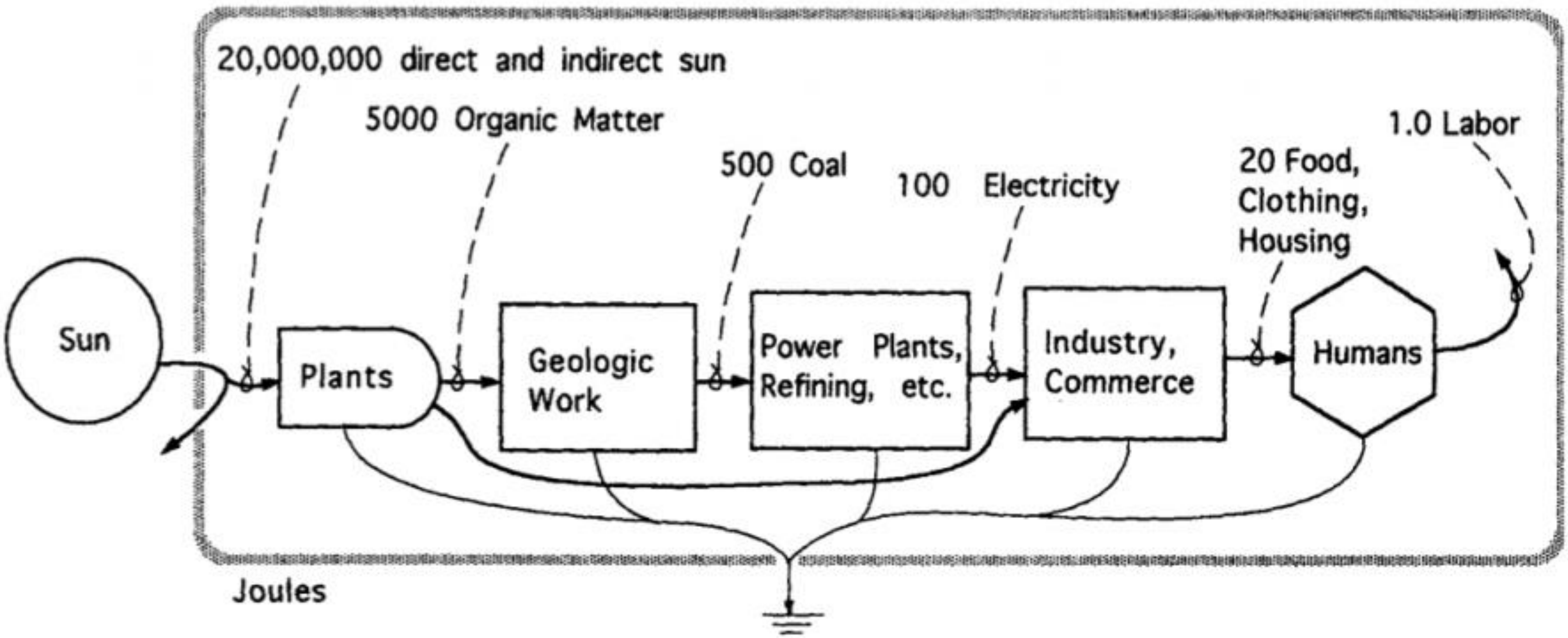


Exergy of a system is the maximum useful work possible during a process that brings the system into equilibrium with the environment



"Efficiency diagram by Zureks" by Zureks - Own work. Licensed under Public Domain via Commons - https://commons.wikimedia.org/wiki/File:Efficiency_diagram_by_Zureks.svg#/media/File:Efficiency_diagram_by_Zureks.svg

Emergy (Embodied energy) is the sum of all the energy required to produce any goods or services, considered as if that energy was incorporated or 'embodied' in the product itself.



"Emergy can be defined as the total solar energy equivalent which is used directly or indirectly to produce goods or services." (*H.T.Odum, 1996, H.T. & E.C.Odum, 2000*)

Available online at www.sciencedirect.com
ScienceDirect
Journal of Cleaner Production 16 (2008) 1907–1914
Journal of Cleaner Production
www.elsevier.com/locate/jclepro

Emergy evaluation of Sicilian red orange production. A comparison between organic and conventional farming

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Available online 4 March 2008

Abstract

This study examines, by using emergy analysis, the production of red orange in Sicily in order to evaluate resource use, productivity, environmental impact and overall sustainability. Four different sicilian farms were studied in order to compare conventional with organic production. Several indices derived from the emergy evaluation were used: the emergy yield ratio (EYR); the environmental loading ratio (ELR); the index of sustainability (SI). Organic orange production appears to use more renewable resources and less purchased energy and materials.

Keywords: Blood oranges; Emergy method; Sustainability index; Organic agriculture

La Rosa A.D., Siracusa G., Cavallaro R.,2008 **Emergy evaluation of Sicilian red orange production. A comparison between organic and conventional farming.** Journal of Cleaner Production 16:1907-1914

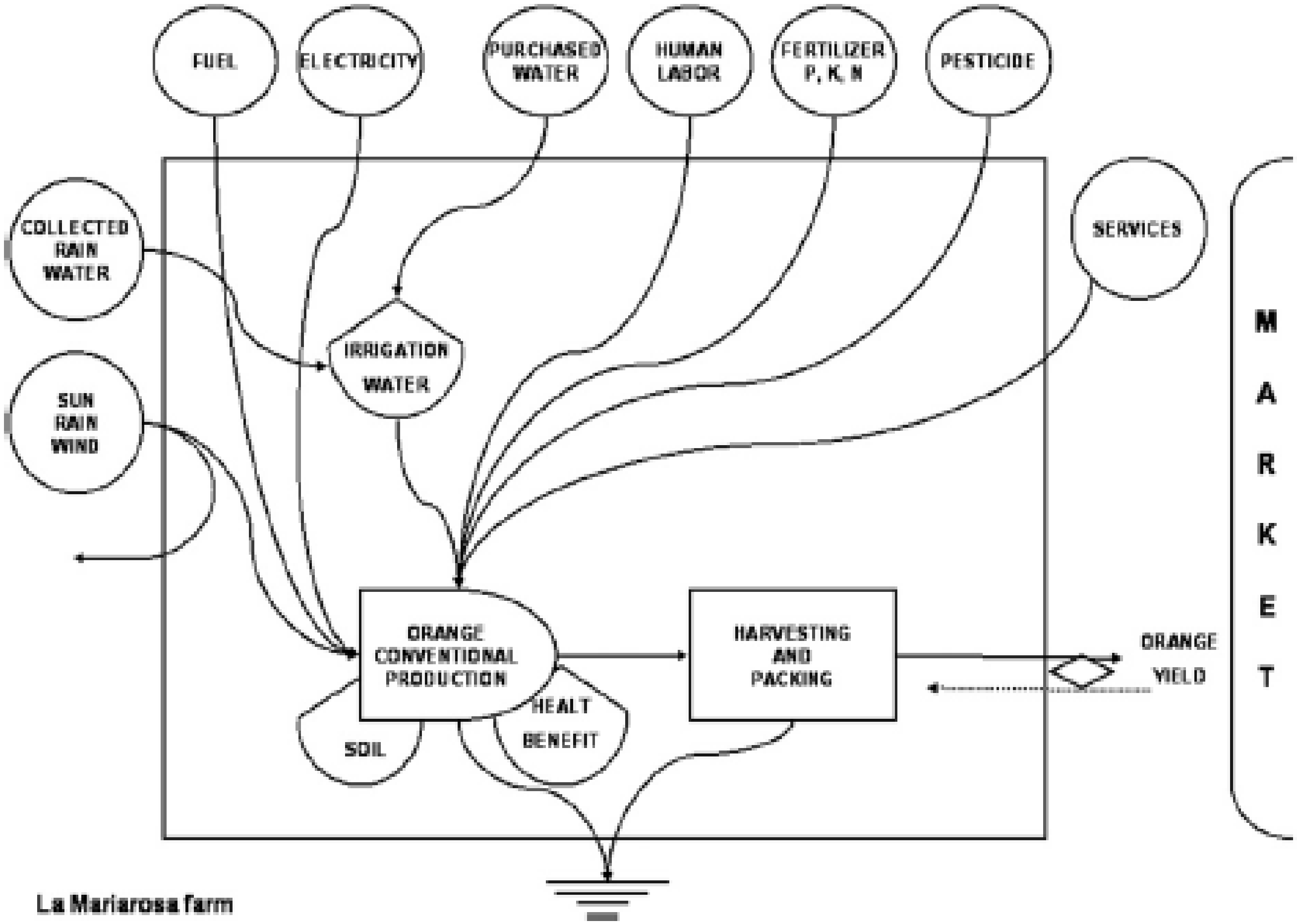


Fig. 1. Energy systems diagram of the conventional orange production of La Mariarosa farm.

La Rosa A.D., Siracusa G., Cavallaro R.,2008 **Emergy evaluation of Sicilian red orange production. A comparison between organic and conventional farming.** Journal of Cleaner Production 16:1907-1914

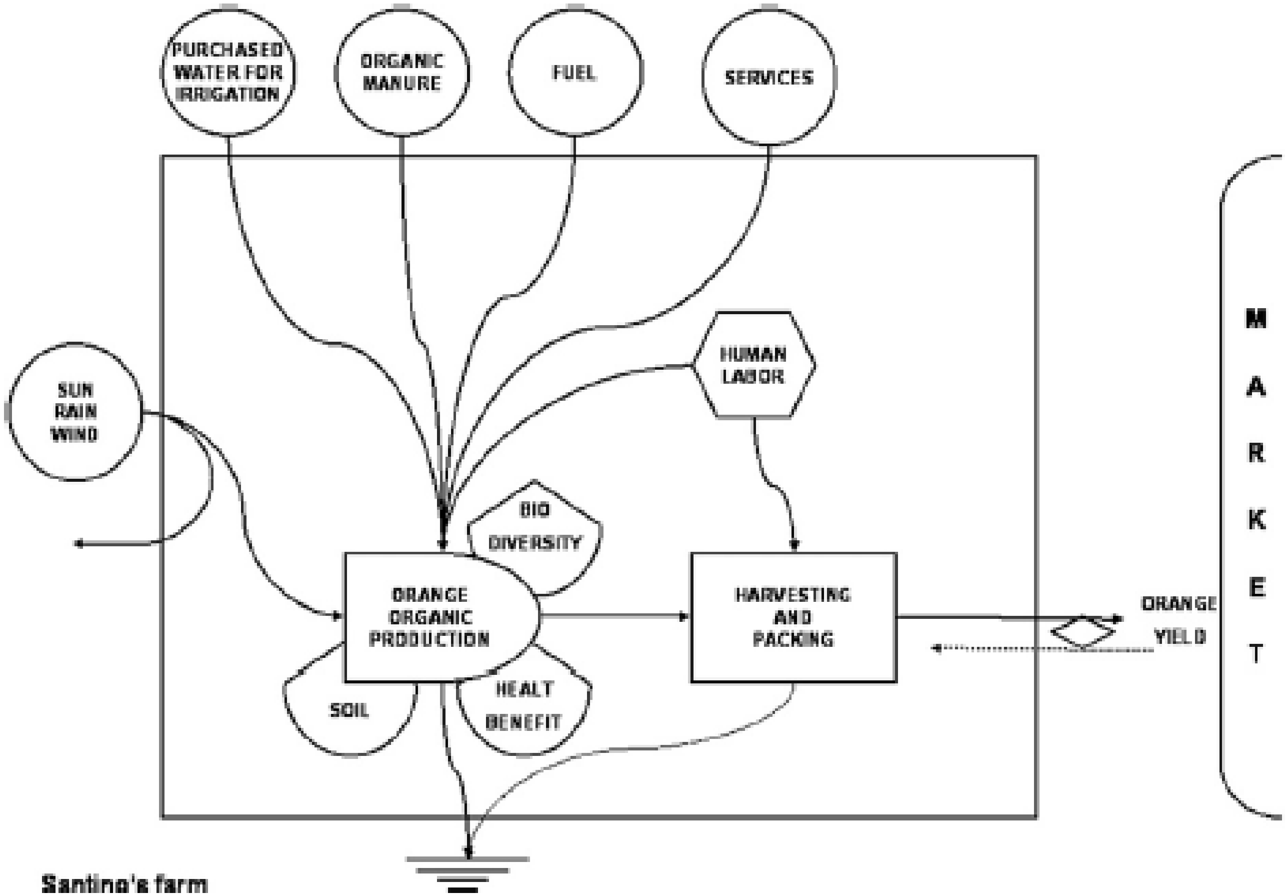


Fig. 2. Energy systems diagram of the organic orange production of Santino's farm.

La Rosa ... on of
Sicilian ... rganic and
conven... 7-1914

Stancanelli, Lentini (SR), organic production; surface area 30 ha; five workers

Note	Item	Data (unit/yr)	Transformity (sej/unit)	Emergy (sej/yr)	Emergy/ha/yr
Renewable resources (*R*)					
1	Sunlight	9.6E14 J	1E00 sej/J	9.6E14	3.2E13
2	Rain	2.9E11 J	18 199 sej/J	5.3E15	1.7E14
3	Wind	2.5E9 J	1496 sej/J	3.8E12	1.3E11
4	Labor (10%)	8E8 J	7.4E6 sej/J	5.9E15	1.9E14
5	Irrigation water	—	—	—	
Sum of renewable				1.2E16	3.9E14
Non-renewable resources (*N*)					
6	Net top soil loss	1.8E12 J	1.24E5 sej/J	2.2E17	7.3E15
Purchased resources (*F*)					
7	Gasoline	3.4E9 J	1.1E5 sej/J	3.7E14	1.2E13
8	Electricity	2.4E11 J	1.43E5 sej/J	3.4E16	1.1E15
9	Organic manure	6E6 g	1.13E8 sej/g[a]	1.1E14	3.7E12
13	Irrigation water	7.2E10 g	5.12E5 sej/g	3.7E16	1.2E15
14	Services	9.1E3€	1.4E12 sej/€	1.2E16	4.0E14
15	Labor (90%)	7.2E9 J	7.38E6 sej/J	5.3E16	1.8E15
Sum of purchased				1.4E17	4.5E15
Product evaluation					
15	Total emergy	3.8E17 sej		Total emergy/ha/yr 1.2E16 sej	
16	Orange yield	2.4E8 g		Orange yield/ha/yr 8E6 g	
17	Orange emergy per mass	1.6E9 sej/g			

La Rosa A.D., Siracusa G., Cavallaro R.,2008 **Emergy evaluation of Sicilian red orange production. A comparison between organic and conventional farming.** Journal of Cleaner Production 16:1907-1914

Category totals and indices calculated for the four systems under study

		La Mariarosa (conventional, 100 ha)	Santino (organic, family farm, 6 ha)
Category totals			
Emergy yield (sej/ha/yr)	*Y*	2.3E16	1E16
Orange yield (g/ha/yr)	*O*	2E7	5E6
Transformity (*Y*/*O* sej/g)	*T*	1.2E9	2.2E9
Total renewable (sej/ha/yr)	*R*	5.2E14	2.2E15
Total non-renewable (sej/ha/yr)	*N*	7.7E15	7.5E15
Total purchased (sej/ha/yr)	*F*	1.5E16	8.5E14
Indices			
Fraction renewable	$R/(R+N+F)$	0.026	0.2
Emergy yield ratio (EYR)	Y/F	1.5	11.7
Environmental loading ratio (ELR)	$(F+N)/R$	43	3.8
Emergy sustainability index (SI)	EYR/ELR	0.03	3.1

The importance of a life cycle approach for energy use assessment

Life Cycle Thinking

- Overview of hot spot identification

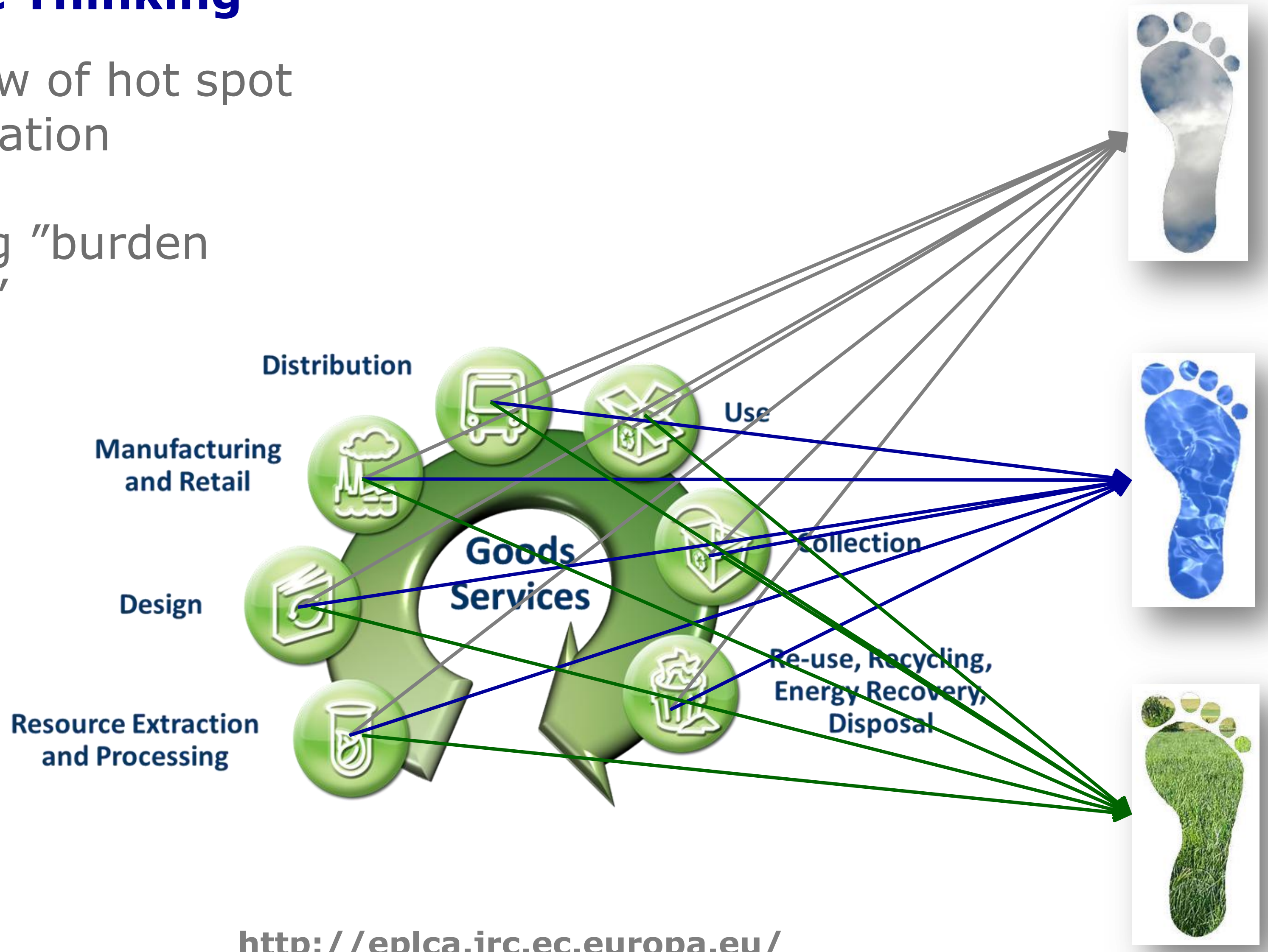
- Avoiding "burden shifting"

http://eplca.jrc.ec.europa.eu/

Life Cycle Thinking

- Overview of hot spot identification

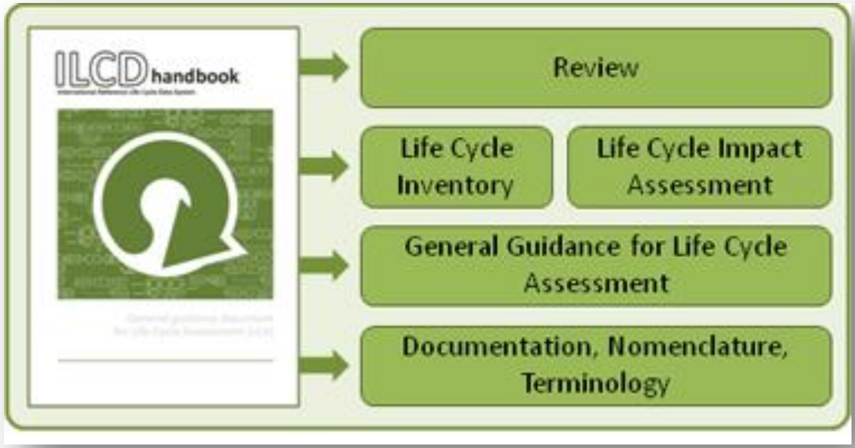
- Avoiding "burden shifting"



http://eplca.jrc.ec.europa.eu/

The **European Platform on LCA** is a project of the European Commission, carried out by the Commission's Joint Research Centre, Institute for Environment and Sustainability in collaboration with DG Environment Directorate Green Economy.

http://eplca.jrc.ec.europa.eu/



System boundaries

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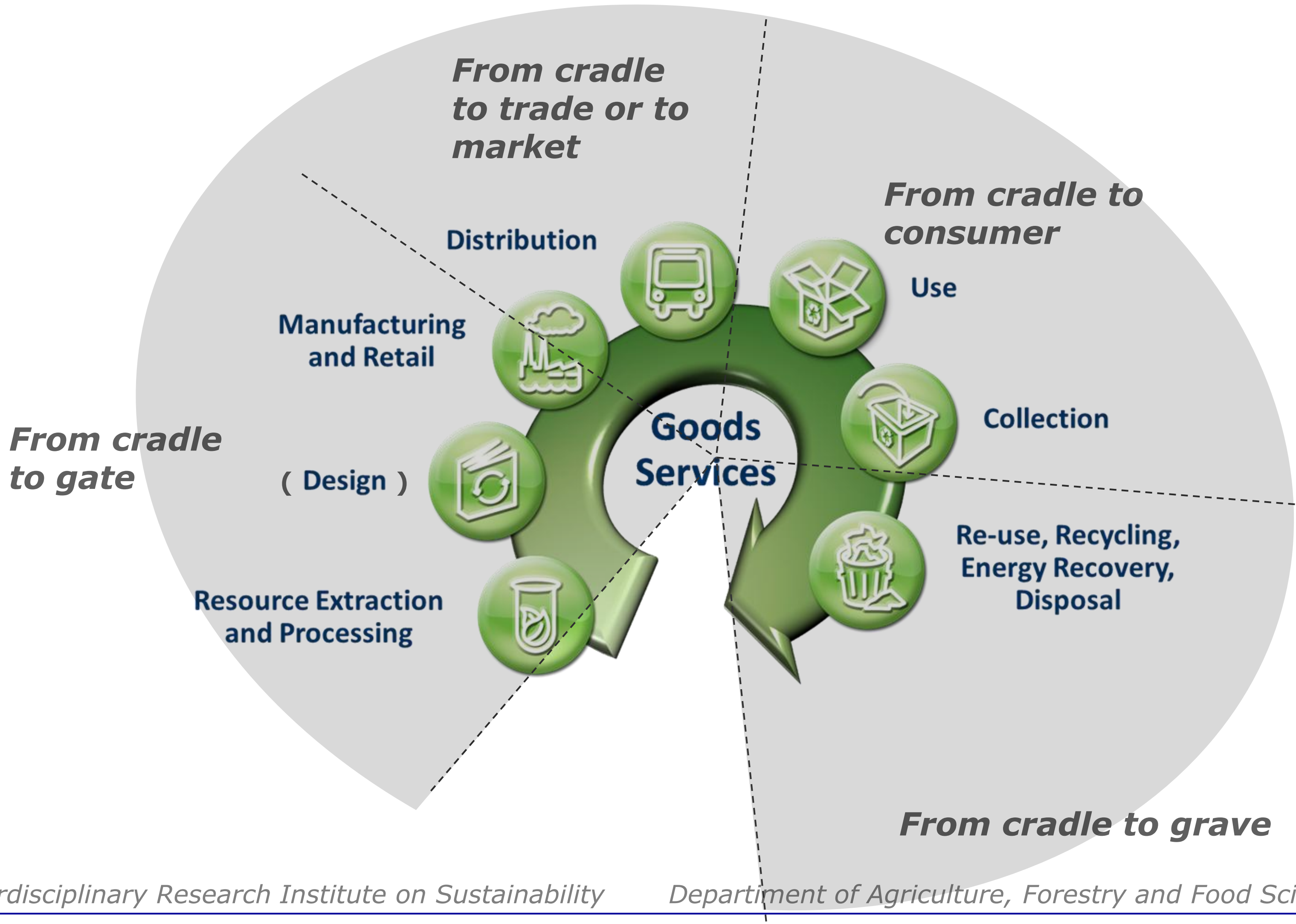

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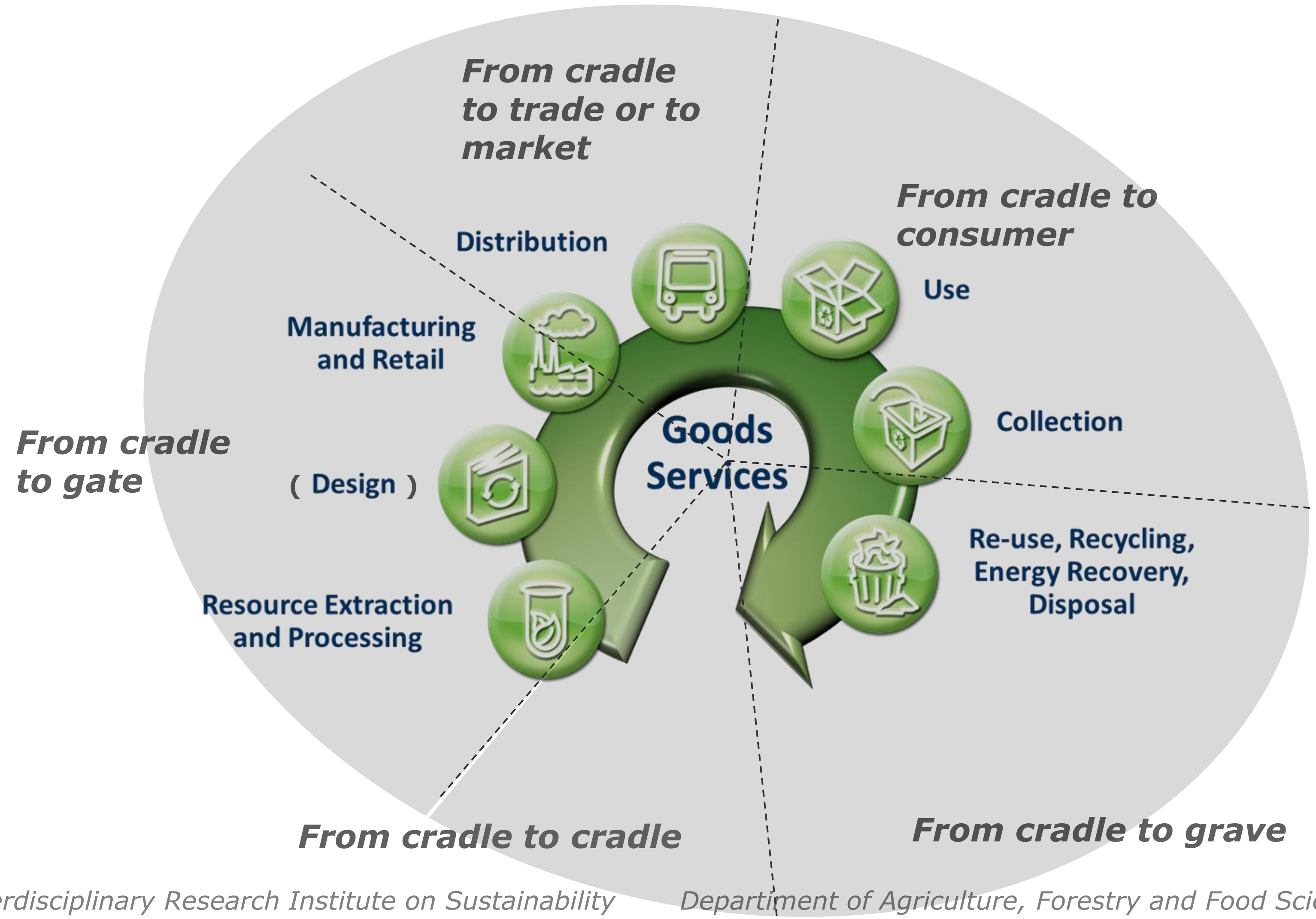

System boundaries

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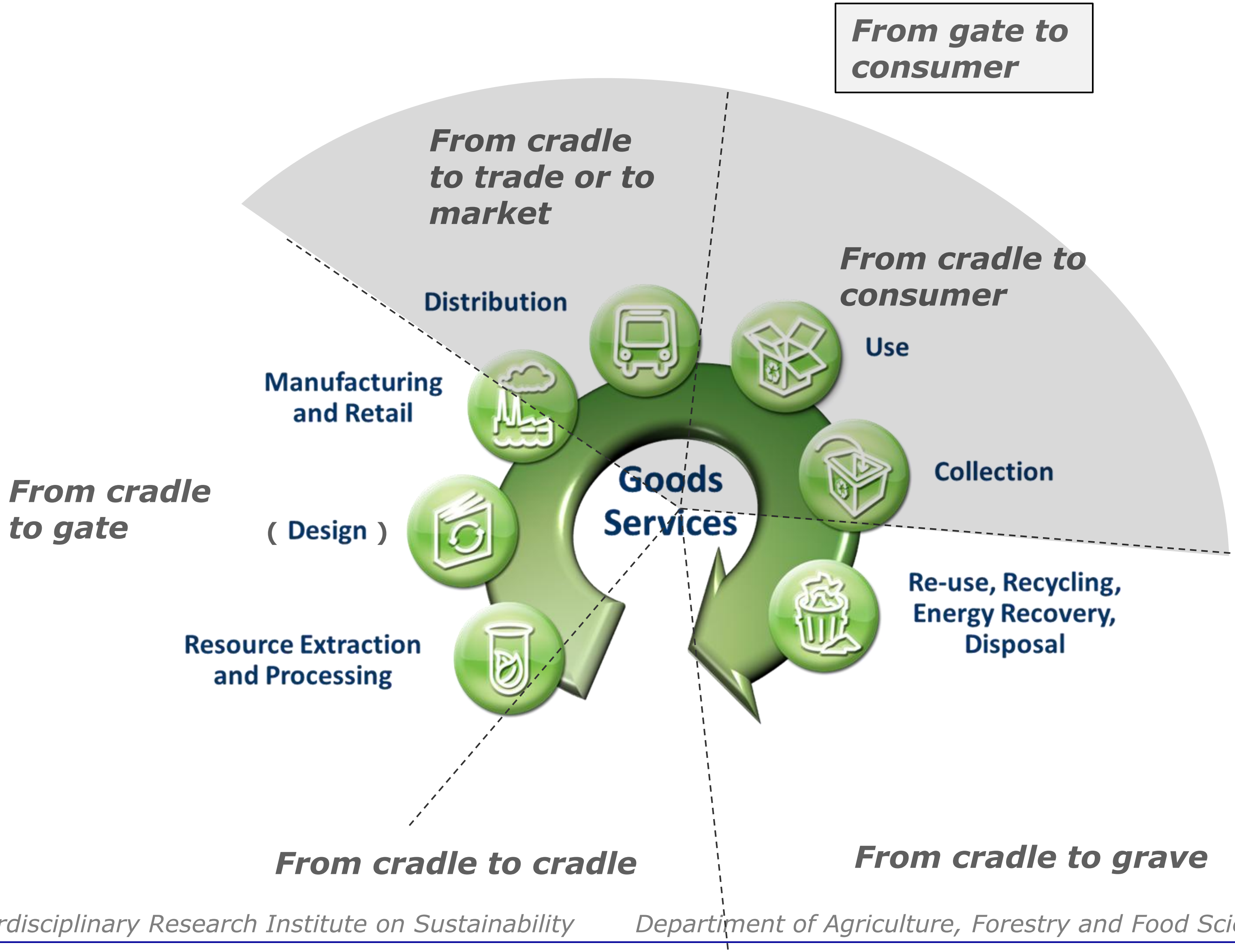

A case study: ancient apple cultivars from Piedmont

Cerutti, A. K., Bruun, S., Donno, D., Beccaro, G. L., & Bounous, G. (2013). Environmental sustainability of traditional foods: the case of ancient apple cultivars in Northern Italy assessed by multifunctional LCA. *Journal of Cleaner Production*, *52*, 245-252.

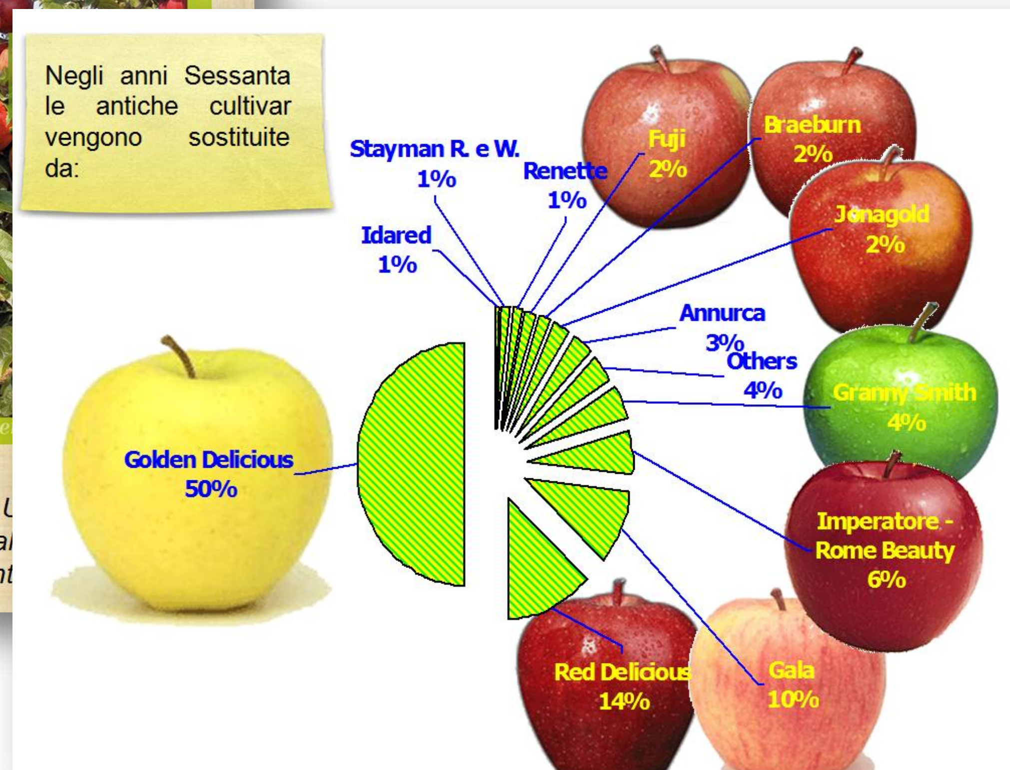

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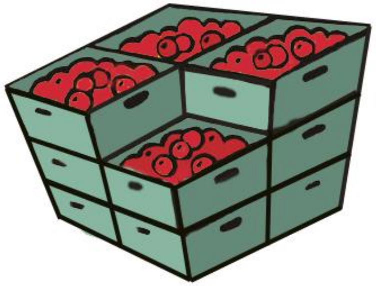
Table 1
Main agronomic properties of the cultivars studied.

Characteristics	Golden delicious	Grigia di Torriana	Magnana	Runsé
Origin	Clay county, West Virginia (United States)	Barge, Cuneo (Italy)	Bibiana, Torino (Italy)	Cavour, Torino (Italy)
Vigour	Medium-low	Medium-low	Medium	High
Flowering period	Early (2nd week of April)	Early (2nd week of April)	Early (2nd week of April)	Early (2nd week of April)
Harvest period	Early (end of September)	Medium-late (end of October)	Late (2nd week of November)	Late (2nd week of November)
Orchard design (cm)	400–450 * 80–100	450 * 150	450 * 180	500 * 200
Plants per hectare	2200–3000	1450	1230	1000
Yield (t/ha)	40	25	23	20
Wholesale fruit price in 2011 (€/kg)	0.40–0.80	0.60–1.00	0.60–1.00	0.60–1.00



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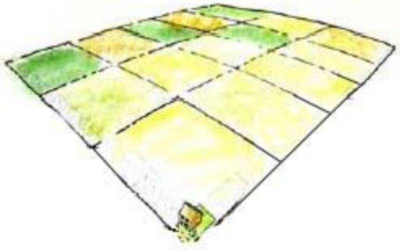

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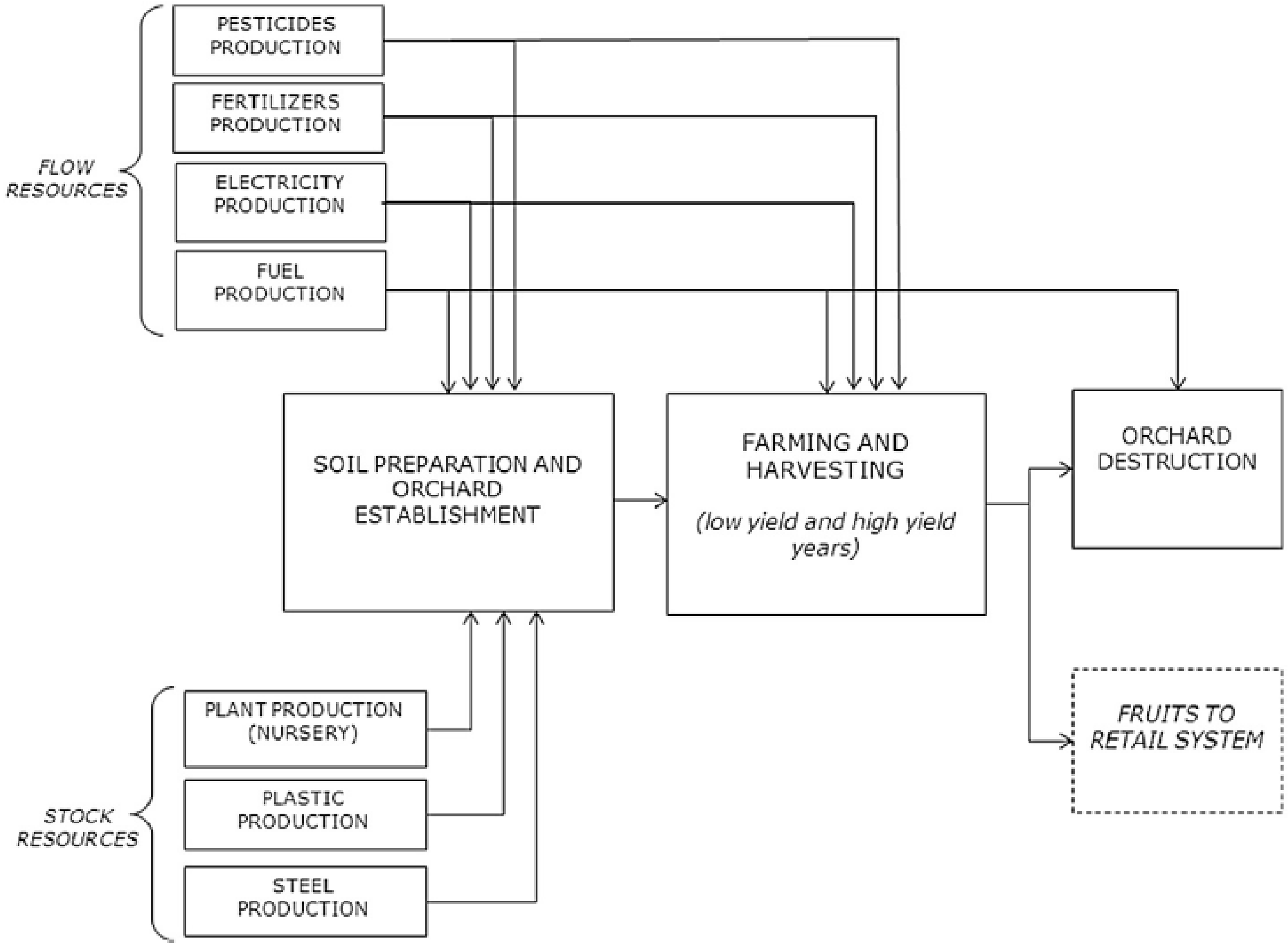
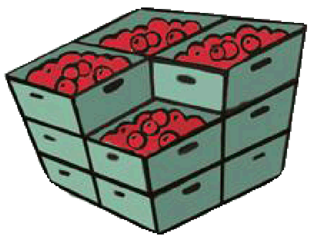
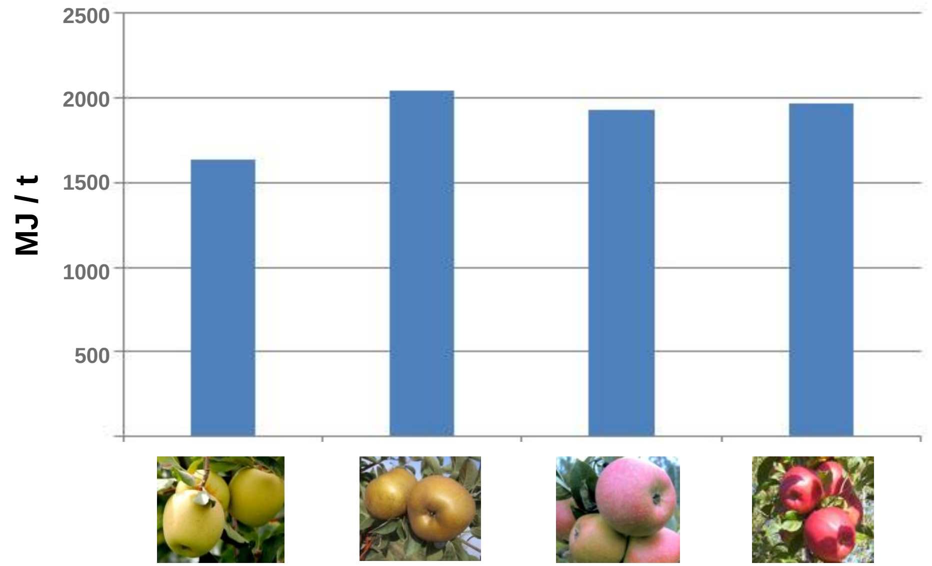
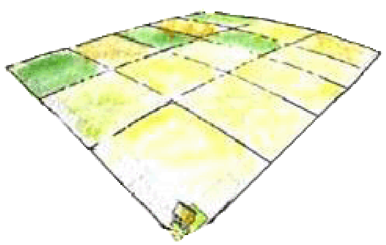


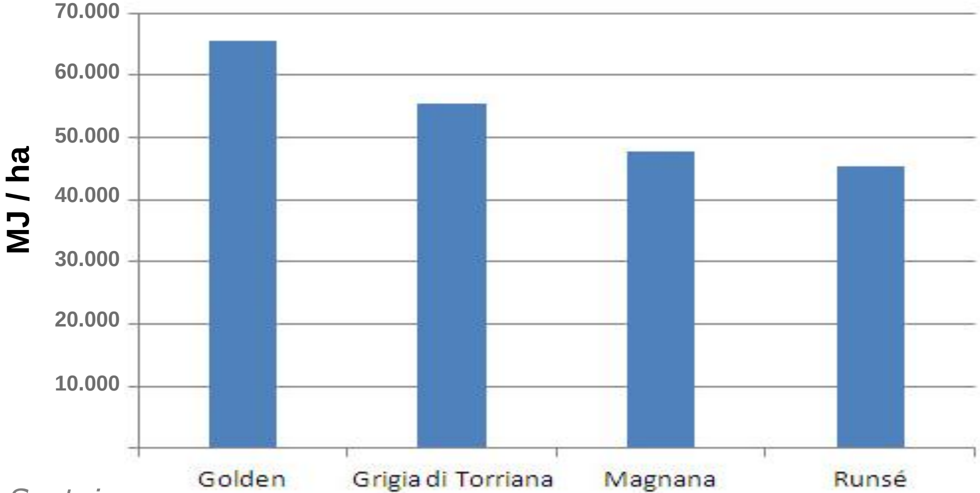
Fig. 1. System boundaries of the study. Dotted line box indicates processes not included in the assessment.

Cerutti, A. K., Bruun, S., Donno, D., Beccaro, G. L., & Bounous, G. (2013). Environmental sustainability of traditional foods: the case of ancient apple cultivars in Northern Italy assessed by multifunctional LCA. *Journal of Cleaner Production*, *52*, 245-252.







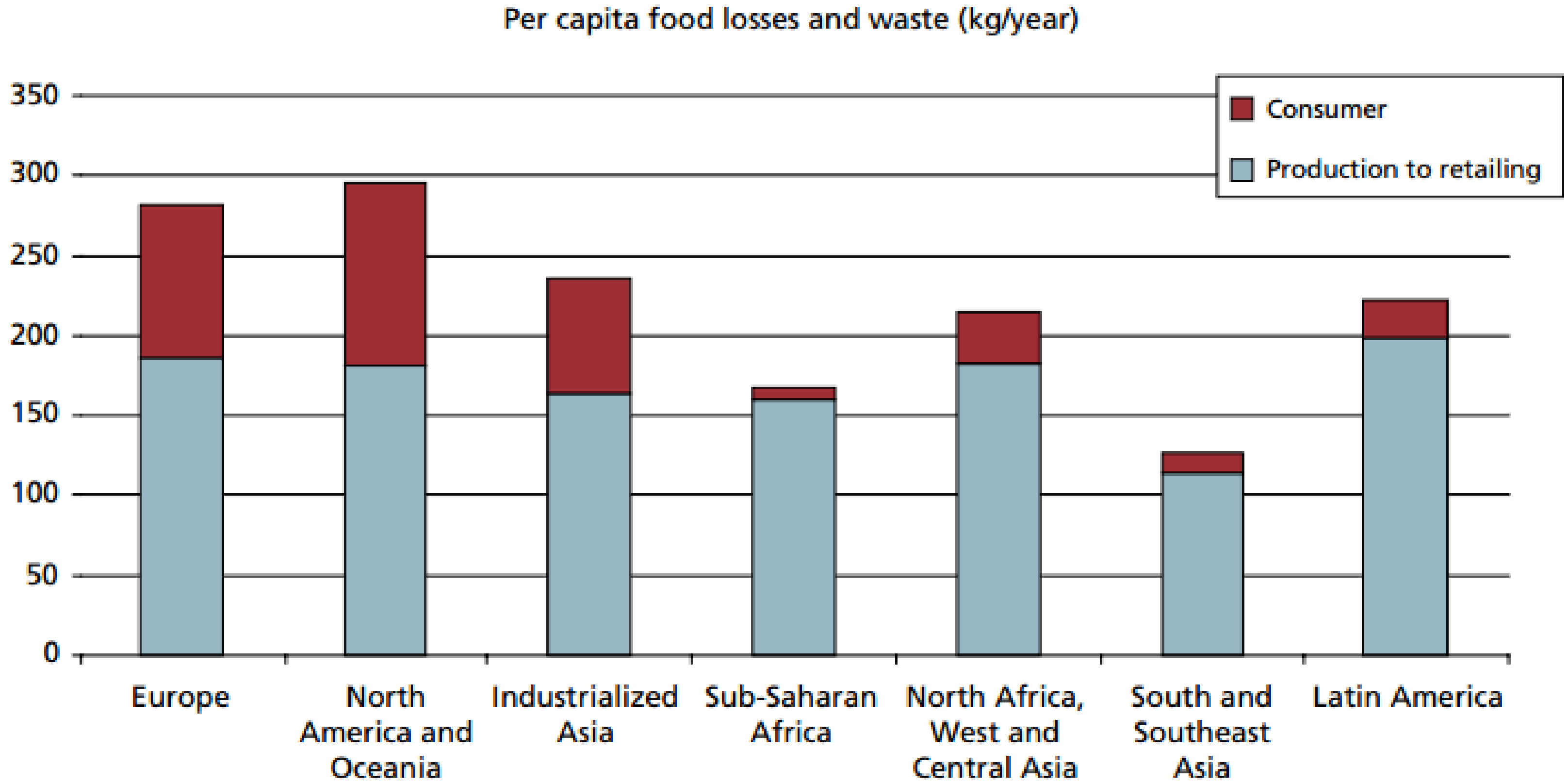


About a third of world production of food for human consumption is lost or wasted throughout the food chain each year (FAO 2011); about 24% when measured in calories.

The percentage rises to 45% for the fruits and vegetables!

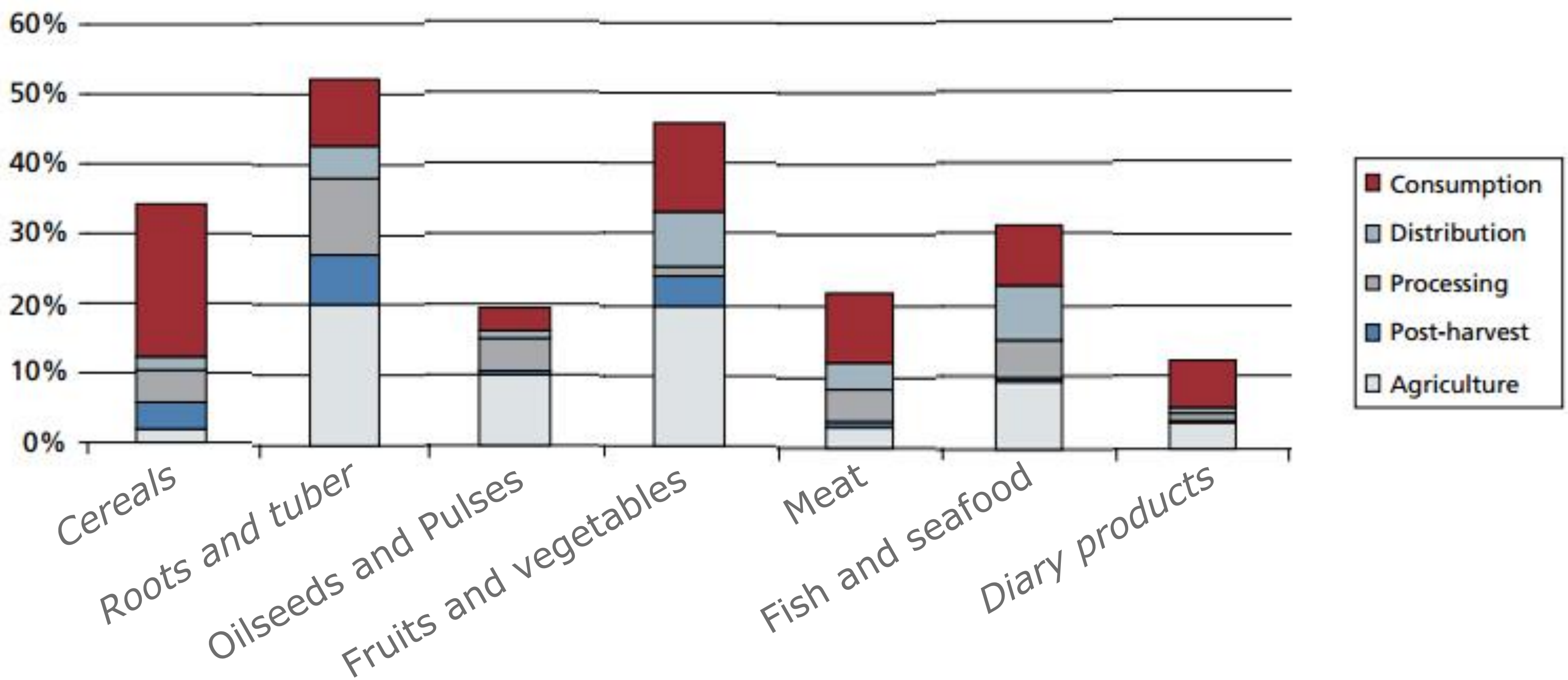
FAO 2011. Global Food Losses and Waste. Extent, Causes and Prevention, available at: http://www.fao.org/docrep/014/mb060e/mb060e.pdf

Figure 2. Per capita food losses and waste, at consumption and pre-consumptions stages, in different regions



FAO 2011. Global Food Losses and Waste. Extent, Causes and Prevention, available at: http://www.fao.org/docrep/014/mb060e/mb060e.pdf

Part of the initial production lost or wasted, at different FSC stages in Europe



FAO 2011. Global Food Losses and Waste. Extent, Causes and Prevention, available at: http://www.fao.org/docrep/014/mb060e/mb060e.pdf

... a very rough estimation of energy wasted in food losses by an average European

	MJ/year
Cereals	2828,28
Roots and tubers	726,95
Oilcrops	748,48
Fruit and vegetables	606,06
Meat	707,07
Fish	187,88
Dairy	1740,74
TOTAL	***7545,47***

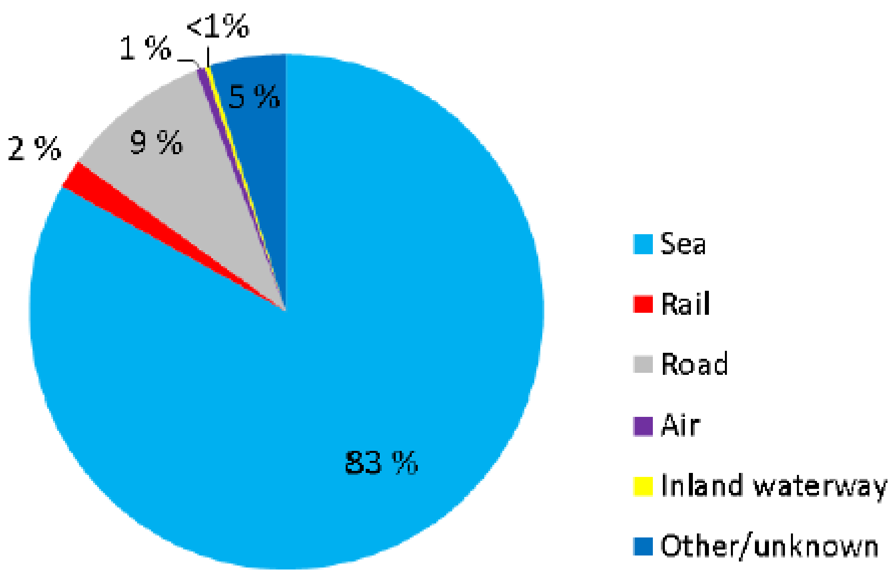
... a very rough estimation of energy wasted in food losses by an average European

	MJ/year	MJ/day
Cereals	2828,28	7,75
Roots and tubers	726,95	1,99
Oilcrops	748,48	2,05
Fruit and vegetables	606,06	1,66
Meat	707,07	1,94
Fish	187,88	0,51
Dairy	1740,74	4,77
TOTAL	***7545,47***	***20,67***

Run a large TV for 20 hours a day!!!

Energy in the food supply chain

Another important element of energy usage in the food transformation industry is transport and logistics, accounting to 9.4% of energy embedded in food consumed in EU-27 in 2013



Means of transport for food imported into the EU- 8 in 2013 (shares). Source: Eurostat — ComExt, 2015.

European Commission, 2015. Energy use in the EU food sector: State of play and opportunities for improvement. Report EUR 27247 EN, Joint Research Centre, DOI: 10.2790/158316

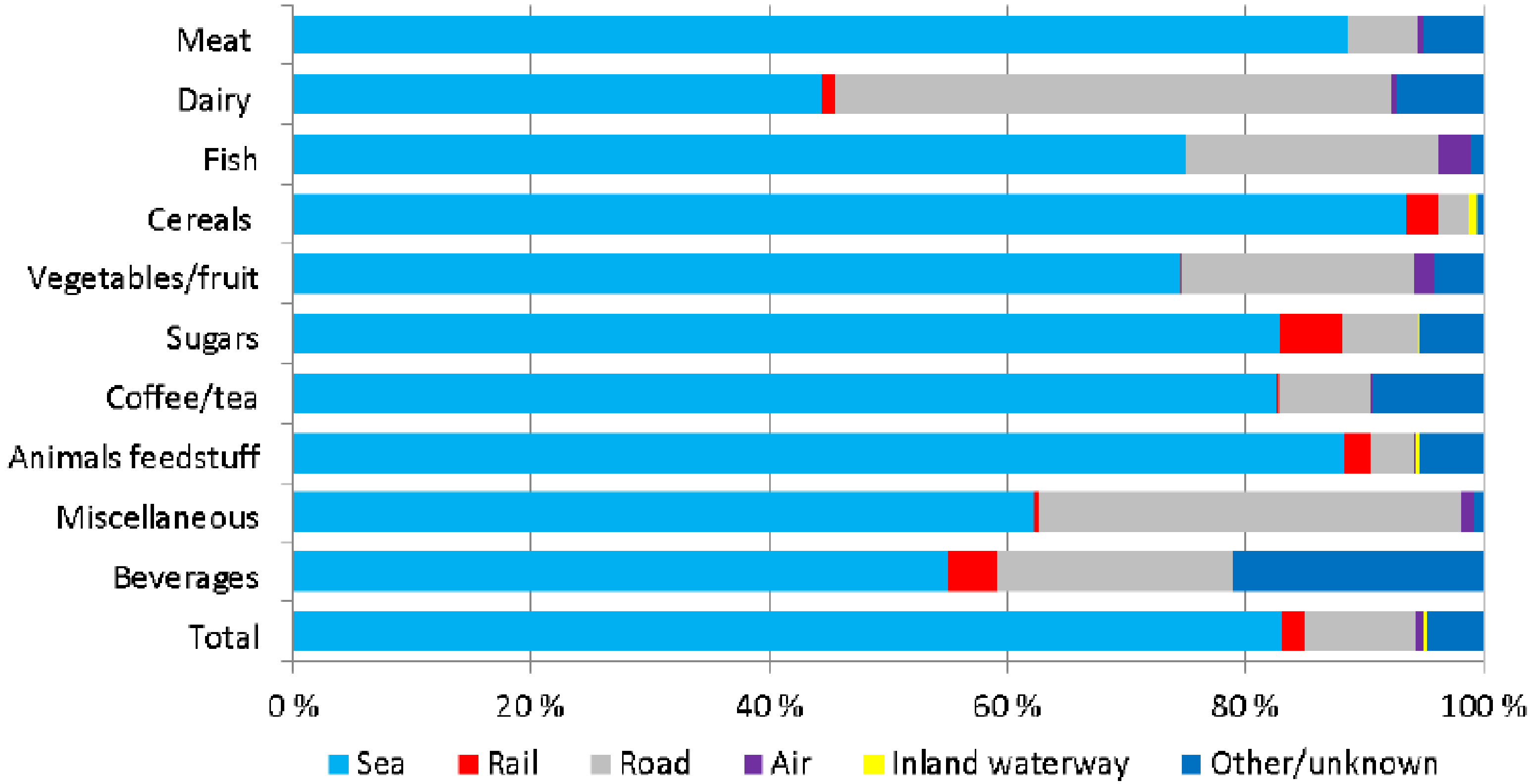


Figure 3.10 Means of transport for food imported into the EU-28 in 2013 (shares for each food category). Source: Eurostat — ComExt, 2015.

European Commission, 2015. Energy use in the EU food sector: State of play and opportunities for improvement. Report EUR 27247 EN, Joint Research Centre, DOI: 10.2790/158316

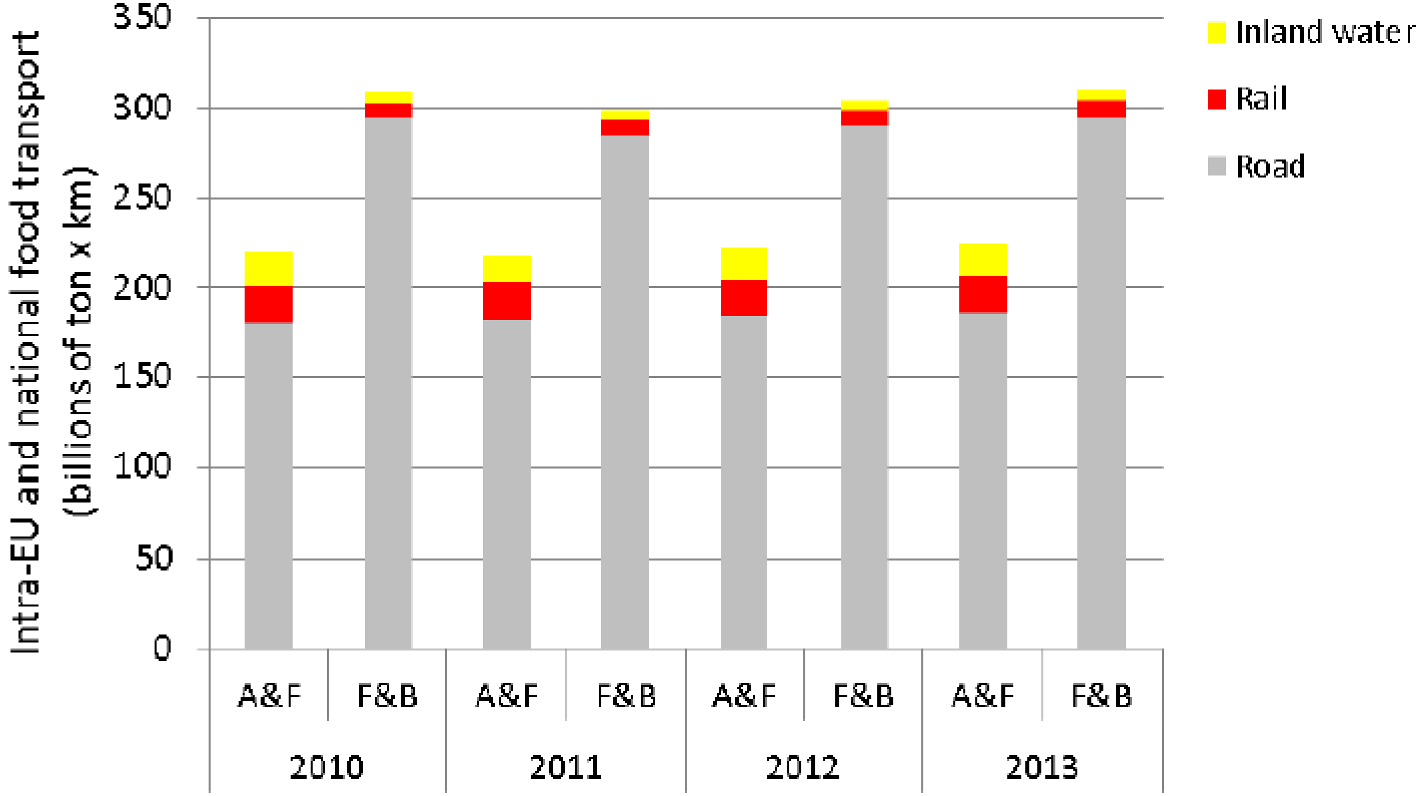


Figure 3.11 Transport of food-related products inside the EU-28 (excluding Malta) in the period 2010-2013. Data from Eurostat [42]
Key: A&F: Agriculture and fishery products; F&B: Food and beverage products.

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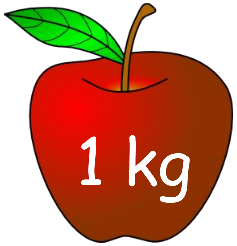

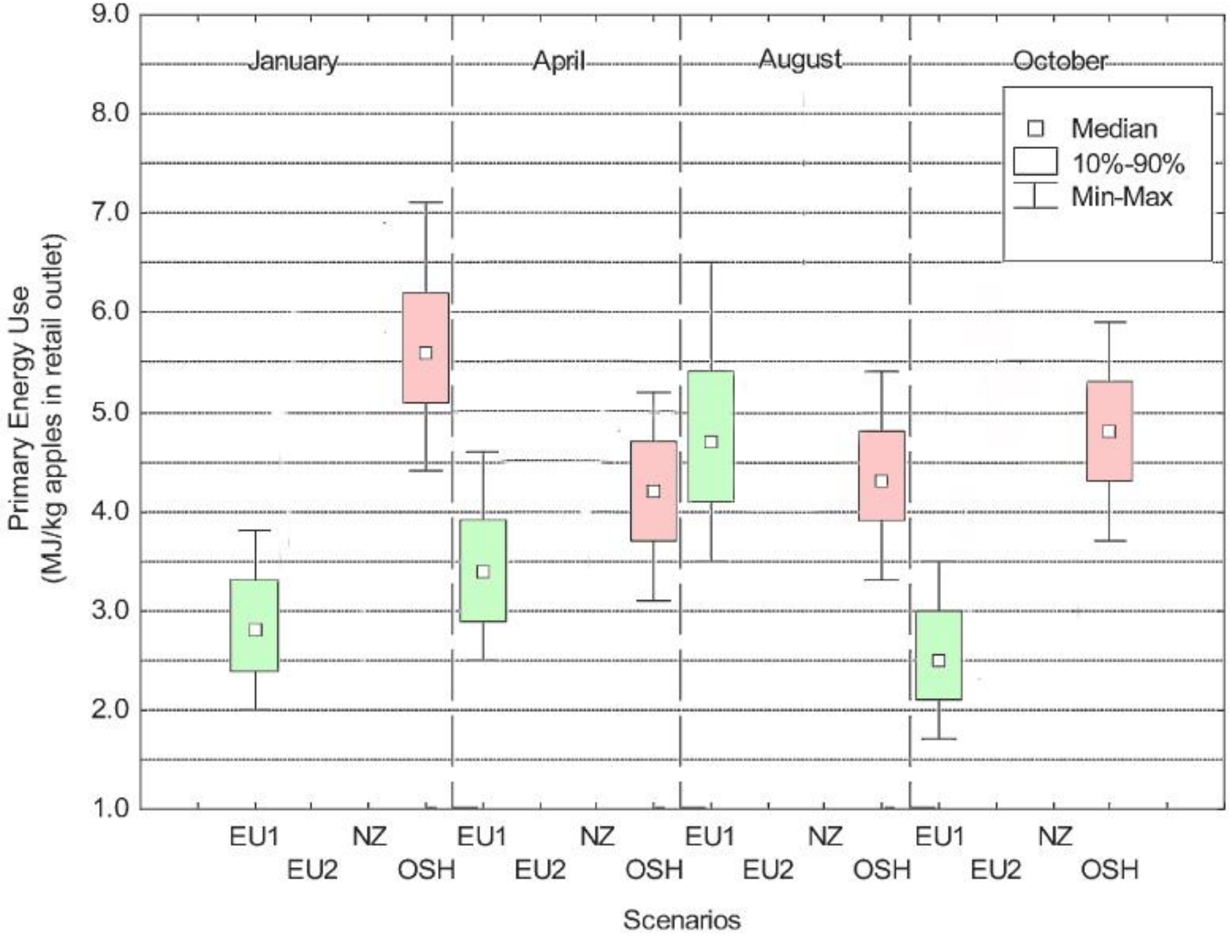

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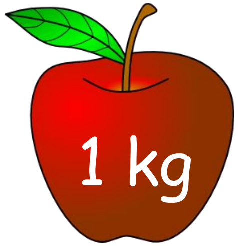

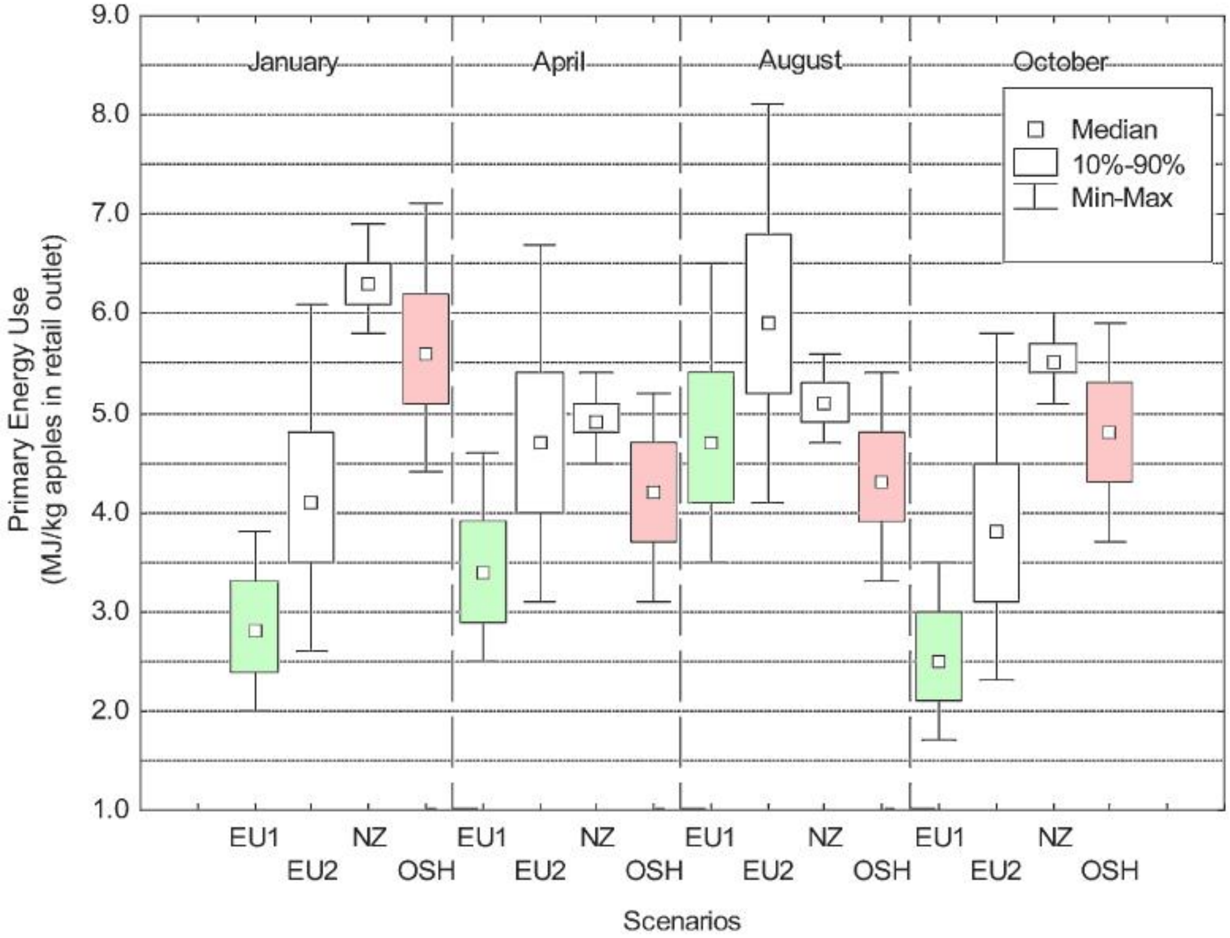

Sustainability from a thermodynamic point of view

Principle of energy conservation

The total energy of an isolated system remains constant—it is said to be conserved over time. Energy can be neither created nor be destroyed, but it transforms from one form to another

Heat energy
Eenrgy from thermal processes

Chemical Energy
Energy from chemical reactions

Electrical Energy
Energy from charged particles

Nuclear Energy
From plitting or combining atoms

Mechanical Energy
Energy of motion (kinetic energy)
Energy associated with position (potential energy**)**

Cerutti, A. K., Calvo, A., & Bruun, S. (2014). Comparison of the environmental performance of light mechanization and animal traction using a modular LCA approach. Journal of Cleaner Production, 64, 396-403.

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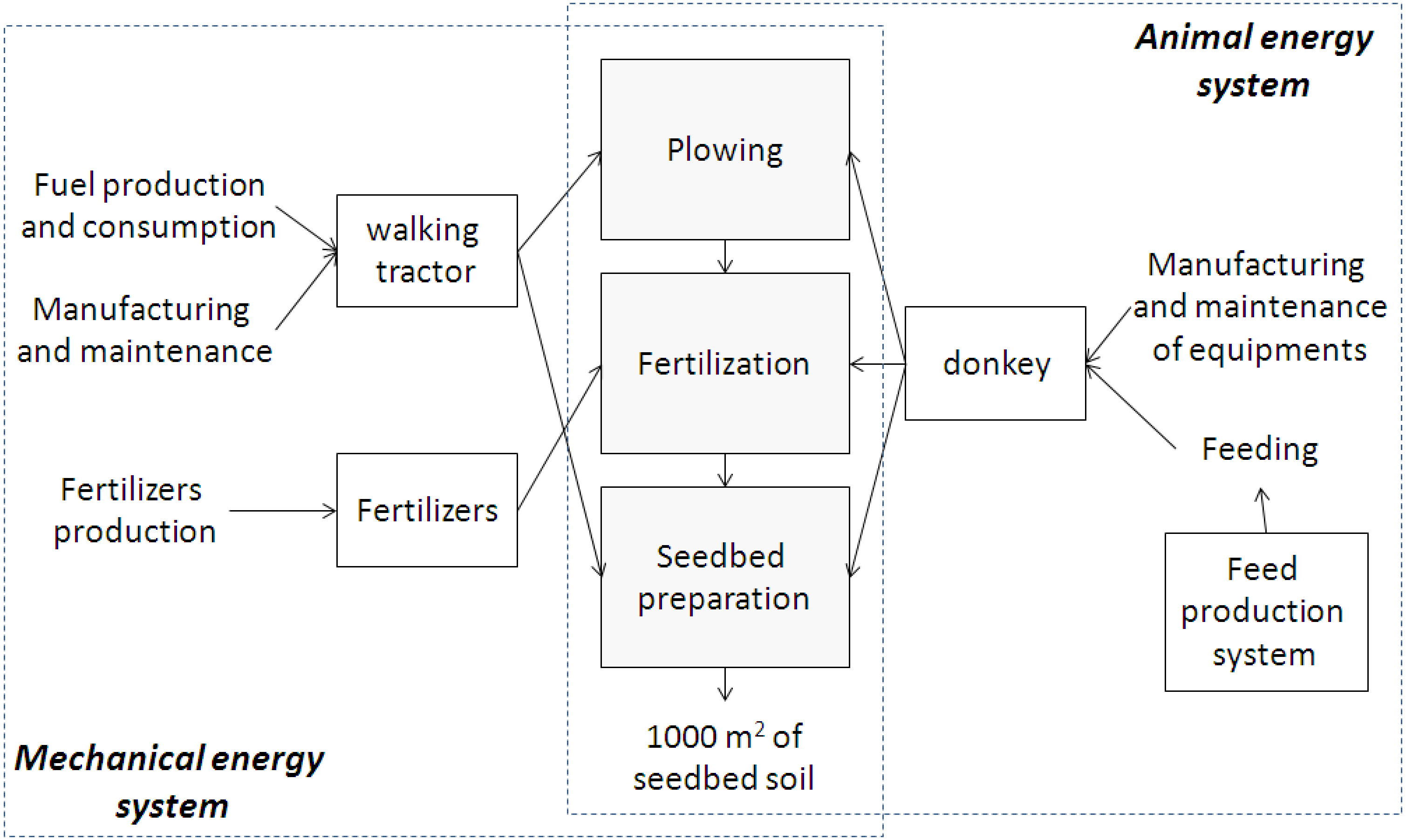

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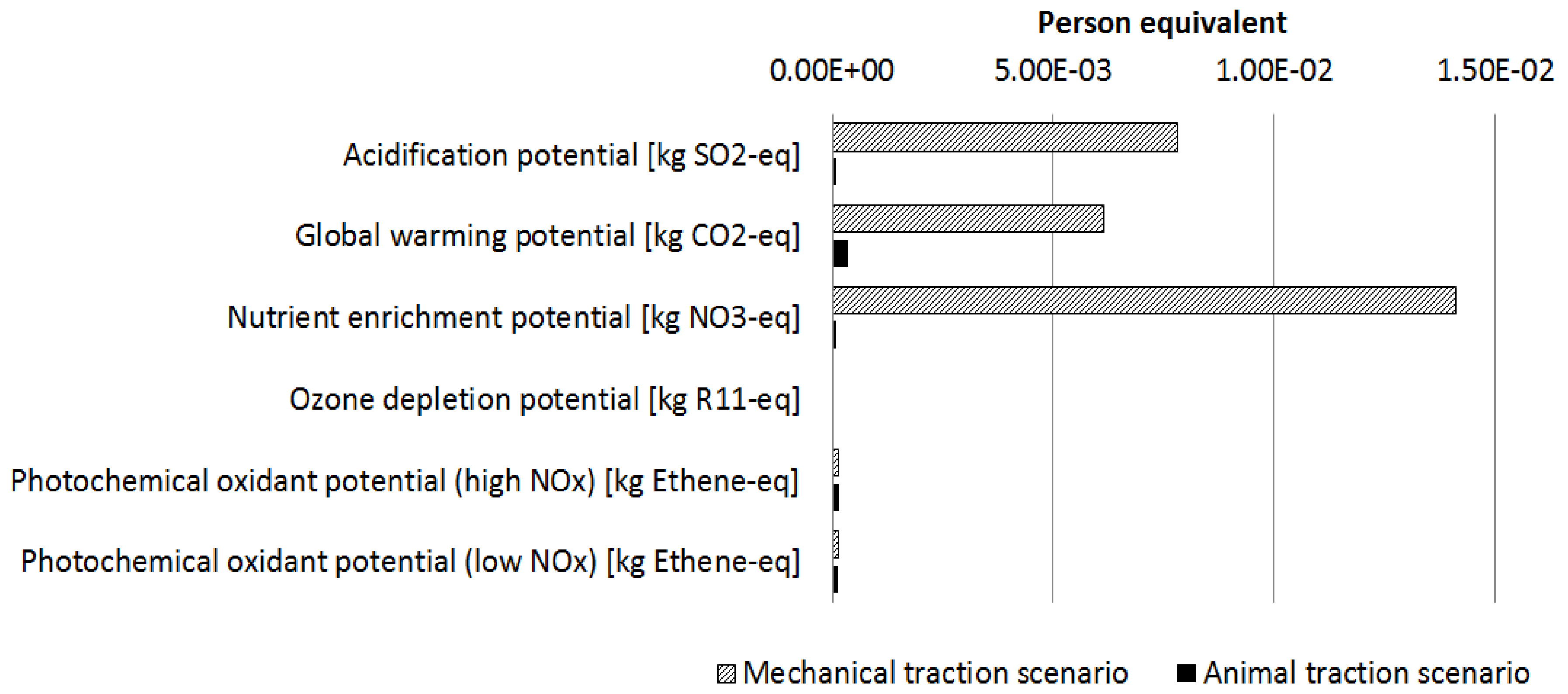

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Taking into account eclusively the *Global Warming Potential*, animal traction allows to save 50 kgCO_2eq./1000 m^2 (94%)

1 kg CO_2-equivalents

Mechanical traction

18.69 m^2 of soil prepared

Animal traction

287.50 m^2 soil prepared

Wada, Y., 1993. **The appropriated carrying capacity of tomato production: comparing the ecological footprints of hydroponic greenhouse and mechanized field operations.** Ph.D. Thesis. University of British Columbia

Local yield

Ecological footprint

Traditional field

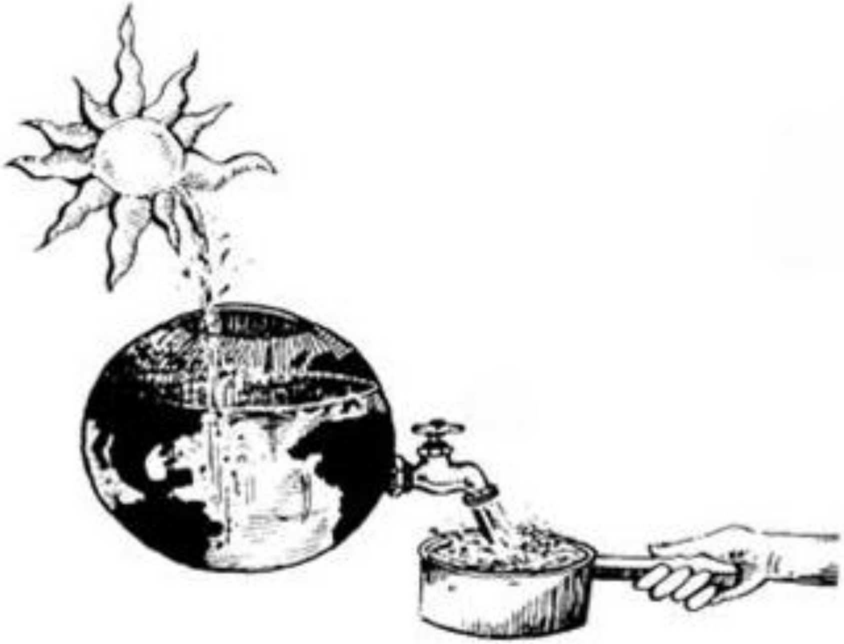
Hydroponic greenhouse

7-9 times bigger

10-20 times bigger

Themodynamic equilibrium

Stationay system

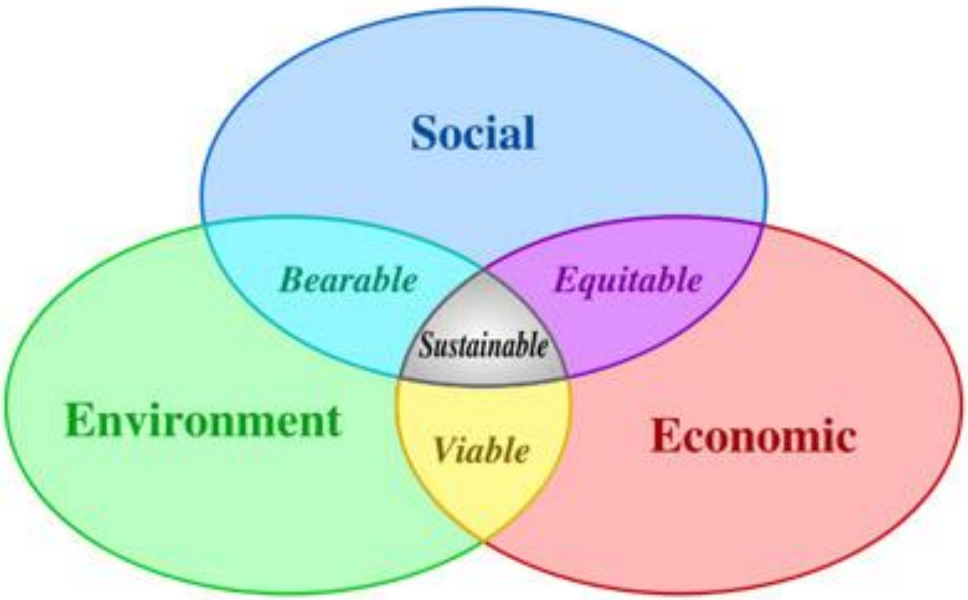


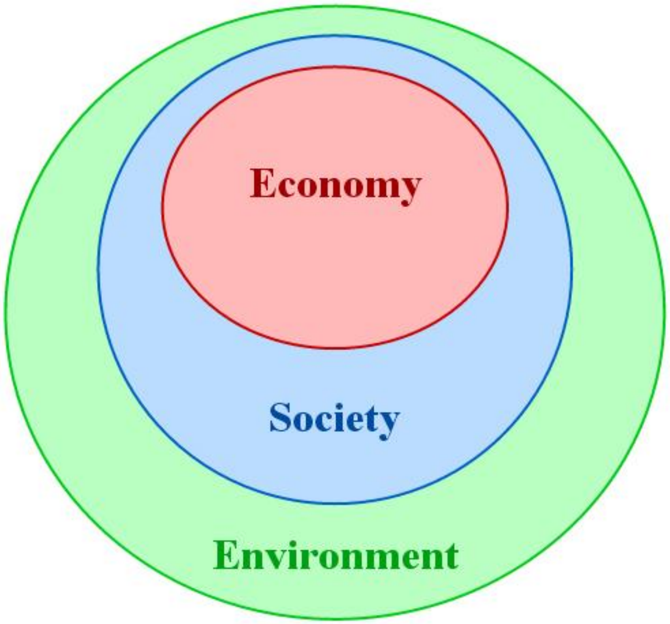
Transient system

Wackernagel, M., & Rees, W. (1998). *Our ecological footprint: reducing human impact on the earth* (No. 9). New Society Publishers.

WEAK SUSTAINABILITY

STRONG SUSTAINABILITY





WEAK SUSTAINABILITY		STRONG SUSTAINABILITY
Natural capital **can** be substituted by human capital	◆	Natural capital **cannot** be substituted by human capital
Technological approach	◆	Ecological approach
Reducing environmental impacts without changing lifestyles	◆	Maining ecosystem resilience at any price

WEAK SUSTAINABILITY

Improve resource use efficiency thorough machineries and materials development, but without changing consumption patterns.

STRONG SUSTAINABILITY

Investigate on productive systems in order to improve the resilience of the ecosystems and to lower the impact on environment even if solution would decrease yield.

Carbon credits

1. Sustainability is primarly a thermodynamic issue

2. Besides emissions, different forms of energy have different environmental burdens

3. A life cycle approach is essential to avoid burden shifting

4. Food miles are important, but they have to be evaluated in a life cycle perspective

Cerutti, A. K., Bruun, S., Donno, D., Beccaro, G. L., & Bounous, G. (2013). Environmental sustainability of traditional foods: the case of ancient apple cultivars in Northern Italy assessed by multifunctional LCA. Journal of Cleaner Production, 52, 245-252.

Cerutti, A. K., Calvo, A., & Bruun, S. (2014). Comparison of the environmental performance of light mechanization and animal traction using a modular LCA approach. Journal of Cleaner Production, 64, 396-403

European Commission, 2015. Energy use in the EU food sector: State of play and opportunities for improvement. Report EUR 27247 EN, Joint Research Centre, DOI: 10.2790/158316

La Rosa A.D., Siracusa G., Cavallaro R.,2008 Emergy evaluation of Sicilian red orange production. A comparison between organic and conventional farming. Journal of Cleaner Production 16:1907-1914

Mila i Canals L., Cowell S.J., Sim S., Basson L., 2007. Comparing domestic versus imported apples: a facus on energy use. Env. Sci. Pollut. Res., 14:338-344

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UNIVERSITÀ DEGLI STUDI DI TORINO

ALMA UNIVERSITAS TAURINENSIS

DISAFA - Department of Agriculture , Forestry and Food Science

IRIS – Intedisciplinary Research Institute of Sustainability

Eating City Summer Campus

The impact of our daily food system into the 4 natural elements.

La Bergerie de Villarceaux

France – 12-22 August 2015

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