PROJECT H2020

LIVERUR

Living Lab Research Concept in Rural Areas

DELIVERABLE 3.6:

Feasibility assessment report on LCA & LCC

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LIVE RUR

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EXECUTIVE SUMMARY

Purpose – Objective: D3.6 gives a clarification to understand the unique potential of circular economy in rural areas, the resource productivity in the waste-related aspects of the circular economy. To that end, all partners in **LIVERUR** project work in a structured and transparent process. The outputs include the identification of rural waste , the interaction of pilot actions through circular rural living labs and proposing end-of-waste case studies for waste streams and sustainable model for life cycle assessment as a decision-making tool for all the actors in existing territorial rural business areas of **LIVERUR**.

Activity: T3.5 redesigned an integration technique for a transition into the circular economy to ensure the sustainability , consumption and extension of the products /services as well as the environmental and socio-economic footprint. Therefore from the Rural Circular Economy framework, T3.6 goes towards and focusing to the extension of product life cycle : **"2. Resource Recovery 3. Product Life Extension".In order to build future scenarios on life cycle thinking, an assessment approach is performed in T3.6.**, which contains all the requirements for the reusable & recyclable materials. Conducting techno-economic and environmental assessments of the whole circular and recycling processes, the evaluation contains the redesign/remanufacture/redesign/redistribute/reuse stages of

the rural waste in production and consumption. The various types of rural waste are identified through LIVERUR 19 pilots in 13 pilot zones via analytical tables (types of waste, identification of circular modes of production, LCA & LCC assessment, completed by waste pathway analysis).

Design/methodology/approach – In D3.6. the life cycle assessment (LCA)[1] is adopted to assess **environmental burdens associated with a shift of rural waste to circular initiatives**. Based on this evaluation framework **a life cycle assessment** (LCA) for reducing resource depletion is combined with **life cycle costing** (LCC)[2] for evaluating its **economic burden**, and **social life cycle assessment** (S-LCA) for recording its social impacts. Additionally, D3.6. seeks to establish an environmental footprint of circular modes of production, either relative to other circular modes (recycling vs remanufacturing), or relative to more traditional modes (recycling vs primary material production).

Findings – The outcomes of D3.6. will be an 1. analytical table (Table 1) which select the appropriate types of rural waste and identify the circular modes by 19 pilot partners. As a result of Table 2, **LIVERUR** community will support to fill it up the table of life cycle assessment (LCA) in order to make a sample and guide for life cycle costing identification and calculation of each 20 pilots, starting to work **on a waste pathway analysis.**

Originality/value – Compared with life cycle assessment (LCA), **Case Studies on rural waste techniques and samples** would be conducted and to be further developed in the newly created Circular Rural Living Lab in **LIVERUR** targeted regions. This Deliverable summarises some recommendations for further actions mainly in T4.4. and WP5 and WP6.

Keywords - **Rural waste, LCA, LCSA, LCC, S-LCA, agri footprint, health impacts, natural ingredients, environmental impact, socio-economic impact.**

1 **Life Cycle Assessment (LCA)** is a structured and internationally standardised method that quantifies all relevant emissions, resources consumed/depleted, and the related environmental and health impacts associated with any goods or services.

2 **Life Cycle Costing (LCC)** is an analytical approach to evaluate the cost of a given asset throughout its life cycle.

INTRODUCTION

The ‘circular economy’ presents numerous opportunities to turn rural waste, like agricultural waste, co-products and by-products (AWCB) into high-value products and feed-stocks. **LIVERUR** project forecasted in the DoW, that few analysis have to be conducted on the main 4 pillars of **LIVERUR**, including the rural waste (domestic, industrial, livestock, crops and agri-food etc.) value chain, which is essential to understanding the potential of the bio- or ecological rural economy, and the availability of feed-stocks and recycling raw materials through characterising and quantifying waste streams to identify the various valorisation pathways.

This work is further extended to demonstrate the applications of extracted agricultural wastes in the pilot actions in WP5 and taken as part of RAIN Platform in the circle of Resources in D4.4.of WP4.

As well as the economic viability of new value chains for rural waste (which includes the livestock- or agri-food waste etc.) , evaluating the environmental performance is crucial in determining the suitability and ultimate realisation of potential pathways.

The description of life cycle relates to economy, more specifically, the **cyclicality of micro-economies and innovation**. Originally, it described products, and meant the timeframe in which a product, product group lasts from the start of manufacture and appearance on the market, until the end of manufacture, or leaving from the market. Later, it was expanded for technology, and even organisations, entrepreneurships, related to the companies' strategic activities, investments, and their quests, longterm goal changes. The life cycle's analysis and evaluation is meaningful because any intended or realised innovation (be it product, technological or organisational) can be called successful based on the investment's return.

Life cycle assessment (LCA) methodology is one tool that can be used to assess the potential environmental impact of a product or system against its comparator. LCA is planned to be used predominantly to assess the environmental implications of a system but social LCA and life cycle costing are becoming more prevalent, allowing for a holistic analysis of policy implications.

Life cycle sustainability assessment (LCSA) methodology was added to the initial LCA & LCC initiative in D3.6. for extending the original scope of LCA towards sustainability assessment , which includes all the environmental, economical and social negative impacts and benefits towards more sustainable products throughout their life cycle.

Environmental **Life cycle assessment (LCA)**, **Life cycle sustainability assessment (LCSA)** and **Life Cycle Cost (LCC)** assessments are performed by **LIVERUR** Consortium in WP3, and include all the techno-economic aspects of the technologies to confirm their cost effectiveness. The issues such as efficiencies, consumptions, and the ability to recover and reuse materials are demonstrated in the LEAN and Circular Economy Business Model Canvas (CE-BMC) in D3.5.

Vertical targets of **LIVERUR** are broad vision targets that all the piloting areas will have to chase. They are: Job creation, social cohesion & innovation and **waste reduction**.

1 CIRCULAR ECONOMY APPLIED TO RURAL WASTE PRODUCTION

1.1 What is the circular economy in rural areas?

The **Circular Economy** represent a fundamental alternative to the linear production economic model (take - make – consume – dispose) in rural areas, a **sustainable alternative by several means of reused resources and rural waste** in forms of:

- closing nutrient loops and reducing negative impacts to the environment
- valorising the wastes in various procedure in the agriculture and another rural activities (tourism, craft, forestry etc.)
- production of rural commodities using a minimal amount of external inputs.

The main goal of rural circular economy is leaving sustainable value inside the circle.

Examining the entire rural activities and systems (e.g. livestock- , crop & agri-food waste in agriculture) reveals opportunities at all stages in rural circular economy:

a) from primary production using smart or precision agricultural techniques,
b) to the retail-consumer dialogue and
c) through to the utilisation of wastes into a new products and/or services and/or processes.

D3.6 capitalize an important aspect of the circular rural economy through the rural waste valorisation, which is a crucial point of the LCA, LCSA and LCC assessments, given the fact that LIVERUR intends to integrate circular economy and living lab techniques. [1]

1.2 Towards reducing the rural waste and resources

The need for sustainable rural systems and reduced waste is **driving the development of innovative circular-system solutions** that benefit the environment and improvement of health in the rural economy.

The circular rural economy concept concerns the creation of sustainable growth by maximising the efficiency of resource allocation by producing more **outputs** from fewer **inputs**.

In circular rural systems, there are opportunities **to reuse outputs, such as waste, at all stages of the production process, and use them as inputs for other production chains.**

In many ways, the circular economy (CE) is returning to a traditional approach where all outputs have another use and supply chains are fully integrated.

Within a CE system, the waste is created during the manufacturing process and redesigned and reused and as an input into the production cycle. This creates a semi-closed loop where resources are recycled, **thus reducing the need to add more materials as well as making use of by-products.**

1 AGROCYCLE – "Agricultural Cycle for a circular economy" H2020- WASTE-2015 http://www.agrocycle.eu/

A closed loop, where all waste is reused within the production process, is the most desirable outcome for sustainability and could be the business model of choice for rural economies in the next future.

The circular rural economy might sound exciting with lots of potential, because it involves a radical transition and disruptive technologies away from the predominantly linear model of today.

1.2.1 What is considered rural waste?

The rural waste is produced as a result of various operations. It includes manure and other wastes from farms, poultry houses and slaughterhouses; harvest waste; fertilizer run- off from fields; pesticides that enter into water, air or soils; salt and silt drained and from many other fields of rural activities.

The rural waste by today was unwanted or unsalable materials produced wholly from various rural operations directly related to the growing of crops or raising of animals for the primary purpose of meat.

In the case of livestock industries, the production of meat, milk and eggs generates large volumes of waste with a **significant impact on the environment**. If livestock waste is not adequately managed, there **are risks of water pollution by excess of nitrates or carbon, air pollution by greenhouse gas emissions and soil pollution due to the accumulation of nutrients**. In addition, **animal wastes are generally associated with health risk to humans and animals if not properly managed.**

The impact of crop waste in our environment is lower, but it has direct consequences on air pollution: the incineration of crop residues in field is a common practice to eliminate waste after harvesting.

Some examples of agricultural waste include: grape vines, fruit bearing trees, vegetables, date palm fronds, industrial waste of olive oil production, solid and liquid waste of sheep wool production etc.

1.2.2 Questions to measure the impact: The Circular Economy always uses less resources and waste or it is just different ones?

In order to measure the significant impacts of circular economy in terms of resource and waste management in rural areas , the main questions are:

- Does CE create more jobs and financial flows within the rural economy, or just displace established ones, perhaps with less?
- CE generate businesses founded on 'circularising' rural waste and secured for long-term if the source of that waste comes from an inefficient rural production and process system?

A 'circular efficiency' approach is needed, whereby upstream inputs are minimised (e.g. using precision agriculture) and **downstream residues/byproducts (manures/crop residues) are 'circulated'**. The technological pathways maximise the use of proteins, nutrients and water.

1.3 Five business models driving the rural circular economy

Rural Business models are used to describe and classify rural businesses, especially in an entrepreneurial setting, and are used to explore possibilities for future development in rural communities. The circular rural economy in many respects is very different from the traditional linear way of producing systems as it was mentioned in D3.5. and D4.2.3.

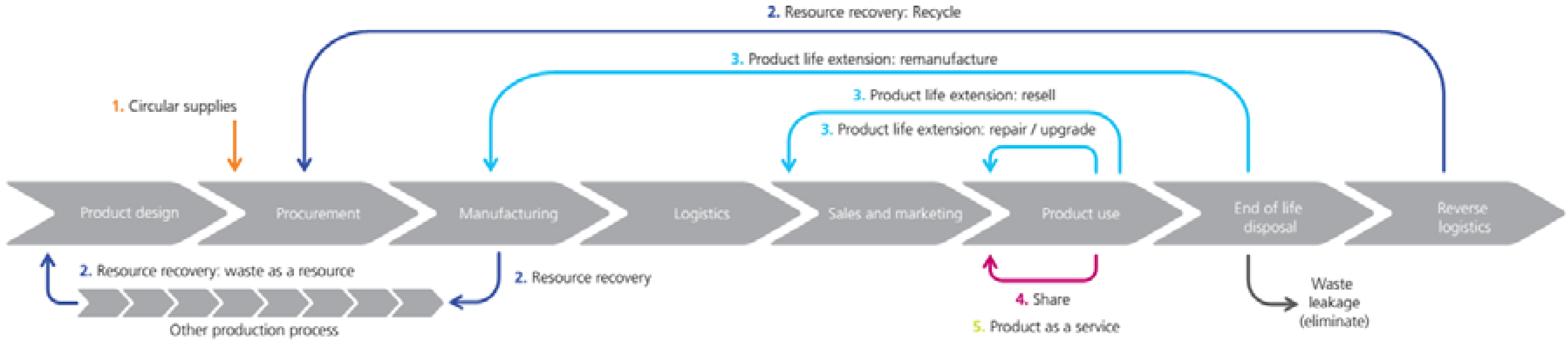
Conventional rural business models have relatively short term horizons as they merely provide solutions for today's rural development problems.

Circular rural business models are more future-oriented as they provide solutions for the local's problems of tomorrow.

In order to be successful in major innovations and in the business models, the users' involvement and real life setting in the rural communities is likely to be required. A more and more in-depth analysis are done in D4.3-D4.4.

There are five underlying business models in the circular economy.

The **Product life extension type business model** allows companies to extend the lifecycle of products and assets. Value that would normally be lost at the end of the life cycle are maintained or improved by repairing, upgrading, remanufacturing or the remarketing of products. And additional revenue is generated thanks to extended usage. Three types of product life extension is considered: stages of remanufacture, resell and repair/upgrade.



1 Circular supplies
This business model is based on supplying fully renewable, recyclable or biodegradable resource inputs that underpin circular production and consumption systems. Through it companies replace linear resource approaches and phase out the use of scarce resources while cutting waste and removing inefficiencies.

2 Resource recovery
This business model recovers embedded value at the end of a product life cycle to feed into another one. This business model promotes return flows and transforms waste into value through innovative recycling and upcycling services.

3 Product life extension
This business model allows companies to extend the lifecycle of products and assets. Values that would normally be lost at the end of the life cycle are maintained or improved by repairing, upgrading, remanufacturing or the remarketing of products. And additional revenue is generated thanks to extended usage.

4 Sharing platforms
This business model promotes a platform for collaboration among product users, either individuals or organisations. These facilitate the sharing of overcapacity or underutilisation, increasing productivity and user value creation.

5 Product as a service
This business model provides an alternative to the traditional model of "buy and own". Products are used by one or many customers through a lease or pay-for-use arrangement. With a 'product as a service' business model product longevity, reusability and sharing are no longer seen as cannibalisation risks, but instead drivers of revenues and costs reduction.

Note: product as a service can be applied at any level in the supply chain and therefore is indicated in the graph.

Source: Accenture (2014, page 12-14)

Figure 1. Five (5) Business models in the Circular Economy. Source: ING Netherlands

2 TOWARDS CIRCULAR MODES IN RURAL WASTE ASSESSMENT

Towards circular modes in rural economies many actors add value to the product extension life.

The entire product life cycle - including waste management system, processing & reprocessing and Manufacturing & reManufacturing of recovered and recycled materials. products and product use etc.-, should be involved in circular material and waste flow (Figure 2).

By preserving information from all life cycle phases and closing the loop, managerial and operational performance could be improved drastically within the Closed-Loop Supply Chain (CLSC).

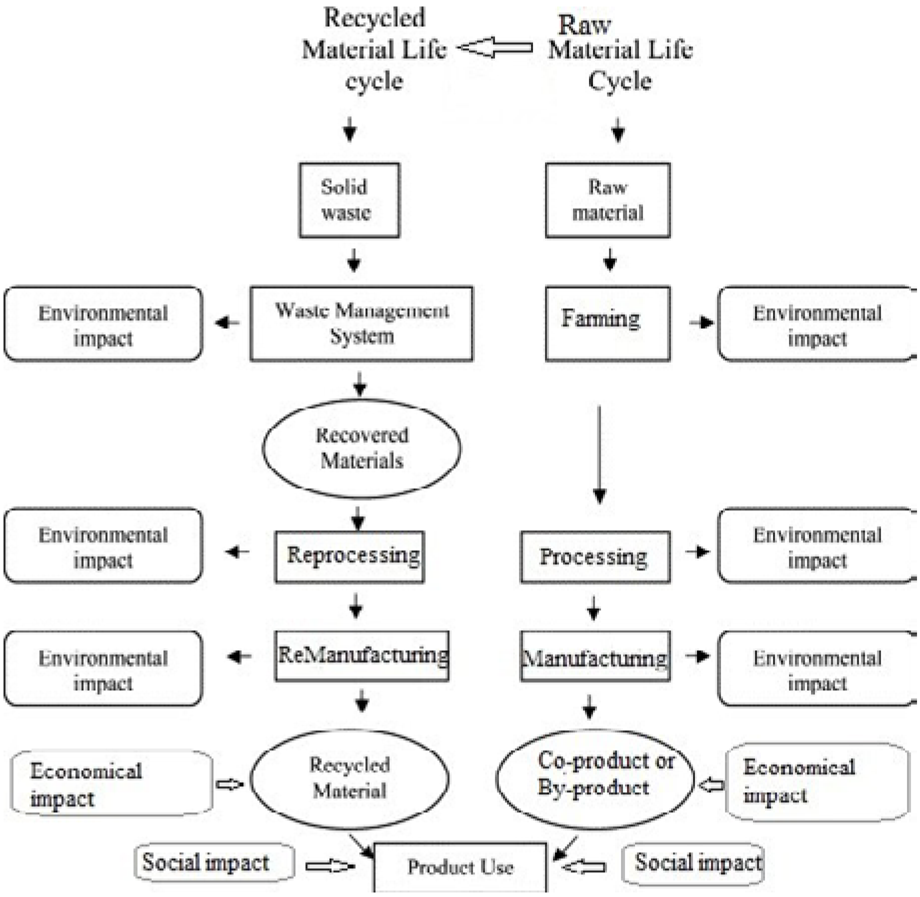


Figure 2. Environmental & socio-economic assessment model of rural waste. Source: modified from S. Ramachandra Rao, 2006

Life cycle assessment (LCA) have been choiced in T3.6. as a decison making tool for circular economy, as it helps introducing to diversify the rural economies in three steps:

A) **In the first step**, the advantages or disadvantages of circular economy are analysed with LCA on a **hypothetical redesigned product, process or service level** in the circular mode.

B) **In the second step**, after getting to know the limits, **it identifies the possible and optimal development alternatives along the life (re) cycle**. This also includes rethinking developments.

C).Finally, **the third step** is to determine **the goal along the business strategy, by which we can start advancement towards circular rural economy**.

2.1 Identification of rural waste in LIVERUR: typologies of rural waste

The form of **waste** (both solid and liquid) generated in **rural areas** is predominantly organic and biodegradable yet it has become a major problem to the overall sustainability of the ecological balance.

Solid Waste: In rural areas, examples of solid waste include wastes from kitchens, gardens, cattle sheds, agriculture, and materials such as metal, paper, plastic, cloth, and so on. They are organic and inorganic materials with no remaining economic value to the owner produced by homes, commercial and industrial establishments. Most household waste in rural areas is organic, with little inorganic material, and is non-toxic. Because of its environment - friendliness, composting is a highly suitable method of waste management in rural areas.

Horticultural waste: refers to tree trunks and branches, plant parts and trimmings generated during the maintenance and pruning of trees and plants all over .

Agricultural waste: **Agricultural waste is waste arising from crop-growing or livestock farming in agricultural holdings**. That includes, for example, materials from crop-growing such as biomass from second or third crops, harvest residues and harvest waste (herbs, grains, root tubers). Waste from livestock farming such as grass, litter or feed is also counted as agricultural waste. (Source: Swiss Federal Office for the Environment).[2]

Liquid Waste: When water is used once and is no longer fit for human consumption or any other use, it is considered to be liquid waste . Wastewater can be sub categorised as industrial and domestic. Industrial wastewater is generated by manufacturing processes and is difficult to treat. Domestic wastewater includes water discharged from homes, commercial complexes, hotels, and educational institutions.[3]

2.2 Identification of open circular modes in 19 pilots actions

The model of circular rural economy is based on closing opened economic flows [Fig 2].

In case of **open processes, intervening in the environment starts with resource extraction, and ends with waste entering the environment as follows (Fig 3).**

Figure 3. Model of open supply chain process. Source: K. Toth Szita.

2 Source: https://www.bafu.admin.ch/bafu/en/home/topics/waste/guide-to-waste-a-z/biodegradable-waste/types-of-waste/agricultural-waste.html

3 Source: http://vikaspedia.in/energy/environment/waste-management/solid-and-liquid-waste-management-in-rural-areas

The main elements of the circular modes in sustainable rural supply chain are (Fig 2):

1.Farming 2. Processing materials 3.Manufacturing products stage (Lean Economy) /Remanufacture & refurbish stage (Circular Economy) 4.Distribution/ Market stage (LE)/ Reuse-Redistribute stage (CE) 5.Use stage (LE)/ Maintenance & Share stage (CE).

All LIVERUR pilot partners were requested to fill up 4 sections to create a basic database of:

- **Type of waste** in pilot action (solid waste or liquid waste)
- **Sector(s)** – Solid waste:horticultural, agricultural with sub-sectors , Liquid waste: domestic or industrial waste water
- **Circular modes** in sustainable rural supply chain (redesign, recollect the raw material, remanufacturing, reuse/recycling, redistristribute, remarketing, recommercialise)
- **Main intervention areas in life cycle assessment** (classical, environmental, social, energy)

The Guideline of Table 1. was sent to the pilot partners to help them in the filling up the individual tables (Annex 1).

	Project partner Region	**Project name**	**Type of waste in your pilot action (Take your choice by X)**		**Sector(s) (Underline the best fit)**		**Circular modes in sustainable rural supply chain (Underline the best fit)**	**Main intervention areas in life cycle assessment (Take your choice by X)**			
1	RMB (AT) South Burgenland	*Living Lab Südburgenland*	Solid waste	X	Horticultural	**Tree tranks** **& branches**	**Redesign**	C L A S S I C A L	E N V I R O N M E N T A L	S O C I A L	E N E R G Y
						Trimmings (leaves etc.)	**Recollect the raw materials**				
							Remanufacturing				
					Agricultural	Livestock -	**Reuse /Recycling**				
					Agricultural	**Crops** -	Redistribute				
					Agricultural	**Agri--food**					
			Liquid waste	X	Waste water	**Doimestic waste water** Industrial waste water	Recommercialize			X	X
2	ADRI (ES) Vega del	*Circular rural business model for biowaste*	Liquid	X	Horticultural	**Tree tranks** **& branches**	**Redesign**	C L S S	E N I R	S O I A	E N R G
						Plant parts	**Recollect the raw materials**				
						Trimmings (leaves etc.)	Remanufacturing				

					Agricultural	livestock		I	O	L	Y
					Agricultural	crops	**Reuse/Recycling**	C	N		
					Agricultural	Agri-food		A	M		
							Redistribute	L	E		
									N		
					Waste water	Domestic waste water	Remarketing		T A L		
			Liquid waste			Industrial waste water	Recommercialize		X	X	
3	UHLA (CZ) Posumavi	*Living Lab in niche products and tourism promotion*	Solid waste	X	Horticultural	**Tree trunks**	**Redesign**	C	E	S	E
						& branches		L	N	O	N
							Recollect the raw	A	V	C	E
						Plant parts	**materials**	S	I	I	R
						Trimmings	**Remanufacturing**	S	R	A	G
						(leaves etc.)		I	O	L	Y
					Agricultural	**livestock**	**Reuse/Recycling**	C	N		
								A	M		
					Agricultural	**Crops**	**Redistribute**	L	E		
									N		
					Agricultural	**Agri-food**	**Remarketing**		T		
			Liquid waste	X	Waste water		**Recommercialize**		L		
						Domestic					
						waste water					
						Industrial					
						Waste water			X	X	
4	TRA (MT)	*Circular Rural Living Lab Malta*	Solid waste	X	Horticultural	Tree trunks & branches	**Redesign**	C	E	S	E
	Malta/							L	N	O	N
	Birkirkara					**Plant parts**	**Recollect the raw**	A	V	C	E
						Trimmings (leaves etc.)	**materials**	S	I	I	R
					Agricultural	**livestock**	**Remanufacturing**	S	R	A	G
					Agricultural	**crops**		I	O	L	Y
			Liquid waste	X	Agricultural	**Agri-food**	**Reuse/Recycling**	C	N		
					Waste water	**Domestic waste wate**		A	M		
							Redistribute	L	E		
									N		
						Industrual waste water	**Remarketing**		T		
						Industrial			A		
						-	**Recommercialize**		L		
						-		X	X	X	
			Solid waste	X	Horticultural	Tree trunks & branches	Redesign	C	E	S	E
	FRCT (PT)							L	N	O	N

5	Terceira Island	*Happy Cows Project*	Liquid waste	X	Agricultural Agricultural Agricultural Waste water	Plant parts Trimmings (leaves etc.) **livestock** **crops** **Agri-food** Domestic waste water **Industrial waste water**	**Recollect the raw materials** **Remanufacturing** **Reuse/Recycling** **Redistribute** Remarketing Recommercialize	ASSICAL	VIRONMENTAL X	CIAL X	ERGY X
6	UL (SI) Slovenia	*Slovenia Dobrna – Šmarje*	Solid waste Liquid waste	X	Horticultural Agricultural Agricultural Agricultural Waste water	Tree trunks & branches **Plant parts** Trimmings (leaves etc.) livestock crops Agri-food Domestic waste water Industrial waste water	Redesign Recollect the raw materials **Remanufacturing** Reuse/Recycling Redistribute Remarketing Recommercialize	CLASSICAL	ENVIRONMENAL X	SOCIAL	ENERGY
7	UL (SI) Slovenia	*Slovenia Solčava - Logarska dolina*	Solid waste Liquid waste	X	Horticultural Agricultural Agricultural Agricultural Waste water	Tree trunks & branches Plant parts Trimmings (leaves etc.) **Livestock** Crops Agri-food Domestic waste water Industrial waste water	Redesign Recollect the raw materials **Remanufacturing** Reuse/Recycling Redistribute Remarketing Recommercialize	CLASSICAL	ENVIRONMENTAL	SOCIAL X	ENERGY

8	UL (SI) Slovenia	***Slovenia- Kungota***	Solid waste	X	Horticultural	Tree trunks & branches	Redesign	CLASSICAL	ENVIRONMENTAL	SOCIAL	ENERGY
							Recollect the raw materials				
						<u>Plant parts</u>	Remanufacturing				
			Liquid waste			Trimmings (leaves etc.)	**<u>Reuse/Recycling</u>**				
					Agricultural	livestock					
					Agricultural	crops					
					Agricultural	Agri-food	Redistribute	X			
					Waste water	Domestic waste water	Remarketing				
						Industrial waste water	Recommercialize				
9	CRAPL (FR) West of France	***Energetic transition for farms in west of France***	Solid waste	X	Horticultural	**Tree trunks & branches**	Redesign	CLASSICAL	**ENVIRONMENTAL**	**SOCIAL**	**ENERGY**
							Recollect the raw materials				
						Plant parts					
						Trimmings (leaves etc.)	Remanufacturing				
			Liquid waste	X	Agricultural	**livestock**	**Reuse/Recycling**				
					Agricultural	**crops**					
					Agricultural	**Agri-food**	**Redistribute**				
					Waste water	**Domestic waste water**	Remarketing				
						Industrial waste water	Recommercialize		X	X	X
10	CRAPL (FR) West of France	***Preserve the ecological condition of drinking water for the city of PORNIC and its inhabitants***	Solid waste	X	Horticultural	Tree trunks & branches	Redesign	**CLASSI**	**ENVIRO**	**SOCIAL**	ENERGY
							Recollect the raw materials				
						Plant parts					
						Trimmings (leaves etc.)	Remanufacturing				

			Liquid waste	X	Agricultural	livestock	Reuse/Recycling	C	N		
					Agricultural	crops		A	M		
					Agricultural	Agri-food	Redistribute	L	E		
					Waste water	Domestic			N		
						waste water	Remarketing		T		
									A		
						Industrial	Recommercialize		L		
						waste water		X	X	X	
			Solid waste	X	Horticultural	Tree trunks	Redesign	C	E	S	E
	ZSA (LV)	*Smart Collaboration for Agriculture*				& branches		L	N	O	N
11	Latvia						Recollect the raw	A	V	C	E
						Plant parts	materials	S	I	I	R
						Trimmings	Remanufacturing	S	R	A	G
						(leaves etc.)		I	O	L	Y
			Liquid waste		Agricultural	livestock	Reuse/Recycling	C	N		
					Agricultural	crops		A	M		
					Agricultural	Agri-food	Redistribute	L	E		
					Waste water	Domestic			N		
						waste water	Remarketing		T		
									A		
						Industrial	Recommercialize		L		
						waste water			X		
			Solid waste	X	Horticultural	Tree trunks	Redesign	C	E	S	E
	ZEKA (TR)	*Olive Excellence Center*				& branches		L	N	O	N
12	Manisa						Recollect the raw	A	V	C	E
						Plant parts	materials	S	I	I	R
						Trimmings	Remanufacturing	S	R	A	G
						(leaves etc.)		I	O	L	Y
			Liquid waste	X	Agricultural	livestock	Reuse/Recycling	C	N		
					Agricultural	crops		A	M		
					Agricultural	Agri-food	Redistribute	L	E		
					Waste water	Domestic			N		
						waste water	Remarketing	X	T		
									A		
						Industrial	Recommercialize		L		
						waste water			X		

13	UCT (IT) Trasimeno	*Efficiency of processes in rural tourism*	Solid waste	X	Horticultural	**Tree trunks & branches**	Redesign	CLASSICAL	ENVIRONMENTAL X	SOCIAL X	ENERGY X
						Plant parts	**Recollect the raw materials**				
						Trimmings (leaves etc.)	Remanufacturing				
			Liquid waste	X	Agricultural	**livestock**	**Reuse/Recycling**				
					Agricultural	**crops**					
					Agricultural	**Agri-food**	**Redistribute**				
					Waste water	**Domestic waste water**	Remarketing				
						Industrial waste water	**Recommercialize**				
14	E 35 (IT) Reggio Emilia	*Cooperativa di Comunità 'Valle dei Cavalieri' Briganti del cerreto'*	Solid waste	X	Horticultural	**Tree trunks & branches**	**Redesign**	CLASSICAL X	ENVIRONMENTA X	SOCIAL X	
						Plant parts	**Recollect the raw materials**				
						Trimmings (leaves etc)	Remanufacturing				
			Liquid waste	X	Agricultural	livestock	**Reuse/Recycling**				
					Agricultural	**crops**					
					Agricultural	**Agri-food**	**Redistribute**				
					Waste water	**Domestic waste water**	Remarketing				
						Industrial waste water					
15	E 35 (IT) Reggio Emilia	*Fuoco commestibile - An Edible Park for citizens*	Solid waste	X	Horticultural	**Tree trunks & branches**	**Redesign**	CLASS	ENVIR	SOCIA	ENERG
						Plant parts	**Recollect the raw materials**				
						Trimmings	**Remanufacturing**				

						(leaves etc.)		I	O	L	Y
			Liquid waste	X	Agricultural	livestock	Reuse/Recycling	C	N		
					Agricultural	crops		A	M		
					Agricultural	Agri-food	Redistribute	L	E		
					Waste water	Domestic			N		
						waste water	Remarketing		T		
									A		
						Industrial	Recommercialize		L		
						waste water		X	X	X	
	DAR (TN)		Solid waste	X	Horticultural	Tree trunks	Redesign	C	E	S	E
16	Quadhref	*Acili Avtiran*				& branches		L	N	O	N
							Recollect the raw	A	V	C	E
						Plant parts	materials	S	I	I	R
						Trimmings	Remanufacturing	S	R	A	G
						(leaves etc.)		I	O	L	Y
			Liquid waste	X	Agricultural	livestock	Reuse/Recycling	C	N		
					Agricultural	crops		A	M		
					Agricultural	Agri-food	Redistribute	L	E		
					Waste water	Domestic			N		
						waste water	Remarketing		T		
									A		
						Industrial	Recommercialize		L		
						waste water			X	X	
	CRAB (FR)		Solid waste	X	Horticultural	Tree trunks	Redesign	C	E	S	E
17	Brittany	*Masha SDC*				& branches		L	N	O	N
							Recollect the raw	A	V	C	E
						Plant parts	materials	S	I	I	R
						Trimmings	Remanufacturing	S	R	A	G
						(leaves etc.)		I	O	L	Y
			Liquid waste		Agricultural	livestock	Reuse/Recycling	C	N		
					Agricultural	crops		A	M		X
					Agricultural	Agri-food	Redistribute	L	E		
					Waste water	Domestic			N		
						waste water	Remarketing		T		

						Industrial waste water	Recommercialize		AL X		
18	CRAB (FR) Britany	***Air and Energy Territorial Plan***	Solid waste	X	Horticultural	Tree trunks & branches	Redesign	CLASSICAL	ENVIRONMENTAL X	SOCIAL	ENERGY X
						Plant parts	**Recollect the raw materials**				
						Trimmings (leaves etc.)	**Remanufacturing**				
			Liquid waste		Agricultural	**livestock**	**Reuse/Recycling**				
					Agricultural	**crops**					
					Agricultural	Agri-food	Redistribute				
					Waste water	Domestic waste water	Remarketing				
						Industrial waste water	Recommercialize				
19	CRAB (FR) Britany	***Dairy Territorial Value***	Solid waste	X	Horticultural	Tree trunks & branches	Redesign	CLASSICAL	ENVIRONMENTAL X	SOCIAL	ENERGY X
						Plant parts	**Recollect the raw materials**				
						Trimmings (leaves etc.)	**Remanufacturing**				
			Liquid waste		Agricultural	**livestock**	**Reuse/Recycling**				
					Agricultural	**crops**					
					Agricultural	Agri-food	**Redistribute**				
					Waste water	Domestic waste water	Remarketing				
						Industrial waste water	Recommercialize				

Table 1. Synthesis table of rural waste & resources in circular mode within 19 LIVERUR pilot actions.

Partners`s comments to their short pilot definition and circular aspects:

To 2. ADRI/ES

Circular aspect:

Only organic matter produced in homes will be used for solid waste. In principle that residue we will try to make composting. Social benefits will be tried by: benefiting people who dispose of their garbage in these containers and generating a niche in the composting plants where solid waste is collected.

To 3. UHL/ CZ

Project in the pilot zone: ŠUMAVAPRODUKT and TURISTICKÁ OBLAST POŠUMAVÍ /CZ:

The core activities of our pilot comprise building up the functional and enchanted partner and stakeholder community to promote and enhance the local heritage , the pleasant smells and tastes of the local products. The traditional local raw materials and food shall be used and promoted – local wood, glass, granite, herbs, traditional fruit and veg, milk and meat products, cereals etc. Promoting local recipes and bringing traditional local dishes back to restaurants is also a challenge, where the natural ingredients can be used as well.

Circularity aspect:

Circularity, of course, means we will point out to all partners that using sustainable materials, re- using, recycling, finding ways for saving energy, material, producing less or minimum waste or wastewater, thinking of resilience in all possible aspects will be an important point in everything we will perform.

To 4. TRA /MT

Project in the pilot zone of Birkirkara/Malta:

The pilot project is about the production of natural herbs and spices for Specialty food ingredients and additives to the low histamine diets through the social farming model.

Circular aspect :

Due to the scarity in Malta, the rainwater harvesting approach will be used during the Farming stage until harvesting. It is a simple, low-cost technique that requires minimum specific expertise or knowledge and offers many benefits. Rainwater is collected on the roof of the main building in Birkirkara and transported with gutters to the storage reservoir, where it provides water at the point of the irrigation system by the pipelines.

To 6-7-8 –UL/SI

6. UL/SI

Project of the pilot zone Padna - Šmarje:

- Connecting young wine makers that are staying in the area and trying hard to professionalise their business
- Joint wine brand “Wine Istria”

- Joint market entry (export) and platform for marketing and selling

Circular aspect:

- Reuse of remains of the grapes in the wine making process
- Grape peels take a lot of time to decompose. When we dry the peels and add special microorganisms we get solid material from which we make flower pots. The pots with small plant (seedling) can be planted directly in soil. It will decompose much faster and microorganisms serve as fertilizer for the plant.
- The material can also be used to make furniture, home decorations etc.
- Making spirits from plant parts (remains of the wine making process)

7. UL (SI)

Project of the pilot zone Solčava - Logarska valley

- Fostering already functioning initiatives (wool processing, wood processing, food processing) and professionalize it with new approaches
- Fostering employment of women

Circular aspect:

- Example wool & Local sheep breed
- Selection of waste wool by local farmers > wool washing, brushing, coloring with plants > Handmade felting products (sholes, slother, jewelry, art products …)

8. UL (SI)

Project of the pilot zone Kungota:

- Connecting young wine makers that are staying in the area and trying hard to professionalise their business
- Joint wine brand “Visit Svečina”
- Joint market entry (export) and platform for marketing and selling

Circular aspect:

- Making spirits from plant parts (remains of the wine making process)

To 13. ZEKA (Turkey)

Circular aspect:

The circular economy model of the Turkish piloting region consists 2 main columns:

1) the provision of a starting material consisting of wet pomace produced by two-phase oil extraction processes,
2) treatment and recycle of olive waste to newly designed products.

The sustainable system is characterized by a much reduced use of inputs and by the reuse and recycling of material outputs (waste is considered a resource and resources have to be maximised within the system).

The Turkish circular economy model that moves towards the closing loop also suggests a drastic reduction or elimination of waste and loss. The proposed pilot action in Turkey focuses on a concept of waste and by-products within the regional agro industrial system, based on the perspective of circular economy. This approach can be achieved through efficient small and industrial scale bioenergy plant, biorefinery and environmentally friendly processes for the production of biomolecules to be employed as active principles in many sectors. In particular, the exploitation of an olive-oil by-product (wet-pomace) as a new source of energy and polyphenol compounds on an industrial scale.

To 16. Dar Margoum (TN)

Circular aspect:

The solid waste in the craft industry can be identified as a green waste during the production of “dar margoum” (berber carpet or rugs) , composed by sheep wools and plant parts (vegetables and herbs) to coloring the wools naturally . The liquid waste comes from the procedure of washing of sheep wools and wastewater after the natural coloring process from vegetables and herbs.

2.3 Analysis and comparison of raw upcycled materials

Deliverable 3.6 in section 1.3. present two waste assessment visualizations:

- **No. 4. Malta :Raw material production, innovative food processing and extraction from plant materials for natural food ingredients and additives , through social farming**
- **No. 16. Tunisia: Sheep wool production and a raw material processing by natural colorisation for dar margoum (berber carpet)**

with characterization of **available rural waste** (solid or/and liquid), co-products and **by-products** (AWCB) and their current methods or uses through the entire circular modes and impacts (environmental, social and economic) .

Deliverable 3.6. provide a scenario in order to define the optimal LCA and LCC through 2 Cases in Malta and Tunisia.

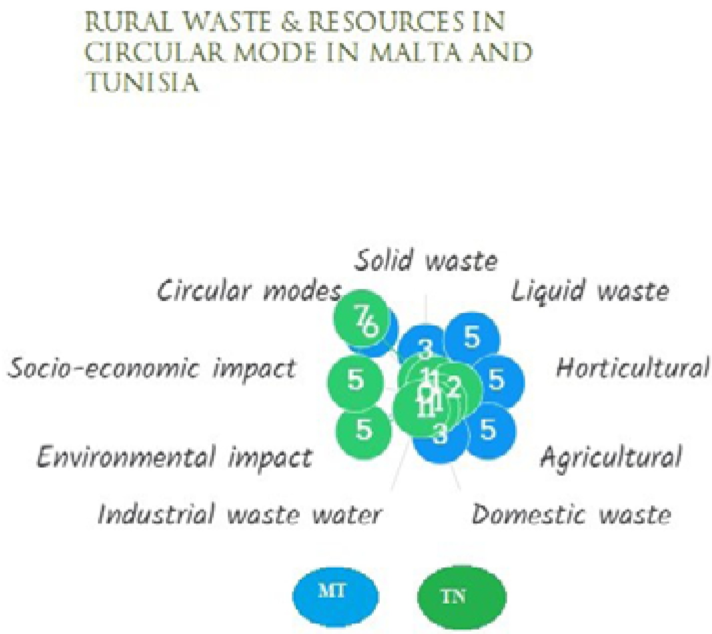


Figure 4. Rural waste and resources in circular mode (MT, TN).

2.3.1 Circularity in production of medicinal and aromatic plants and extracts for natural food ingredients and additives in Malta

The **functional foods** as food products are identical in all aspects to conventional foods except that it contains some **biologically active compound (BAC) as an added ingredient. The pilot activity focus for the production of low histamine food ingredients and additives.**

The main aim is to optimise the production and process efficiency with minimal or no changes in nutritional and biological properties of the selected medicinal ad aromatic plants. **Using the rain-water harvesting** technology in the irrigation system ,there is high expectation to reduce the water consumption and also reduce the energy necessity by the solar panels on the roof of the main building in Birkirkara.

The main efforts will be done on developing a sustainable green water management system and try to build a zero waste and blue water footprint in this water scarcity territory, in Malta.

2.3.2 A circular sheep wool production case

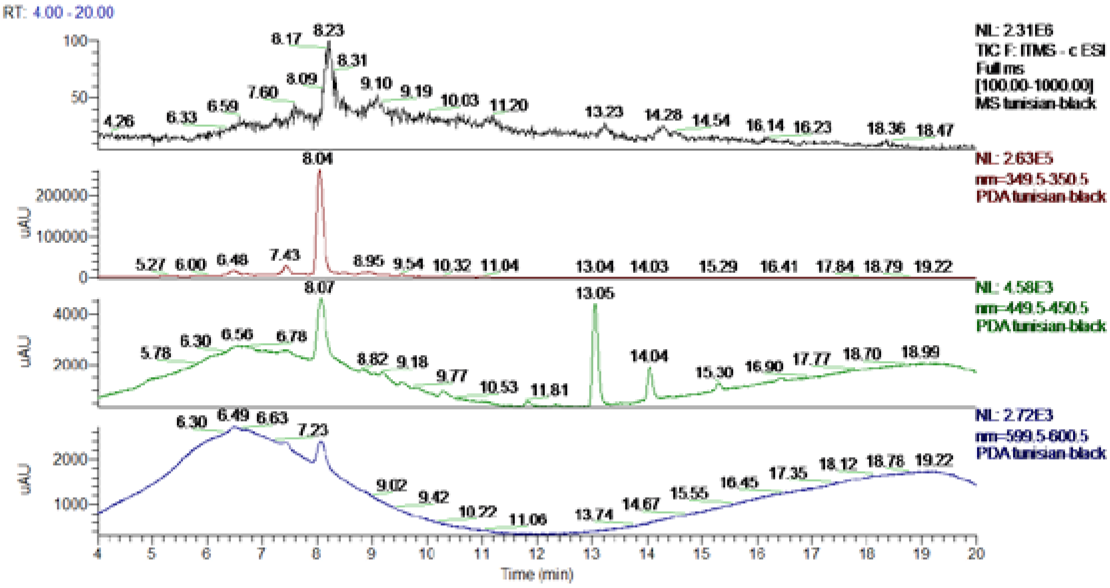
According to the information provided by Mrs **Najwa Gaied from Dar Margoum Association (TN)** from Oudhref and a few other craftswomen, the products used in natural dyeing in sheep wool production are:

- **Vegetable products (oases)**: madder roots, henna, pomegranate bark, aculante centaurea, apple leaf, wild jujube, sagebrush, dry dates ...
- **Animal products:** kermes, cochineal, lacquered ...
- **Various products**: Alum; lime (for fixing colors); Tartar; iron sulfate ..

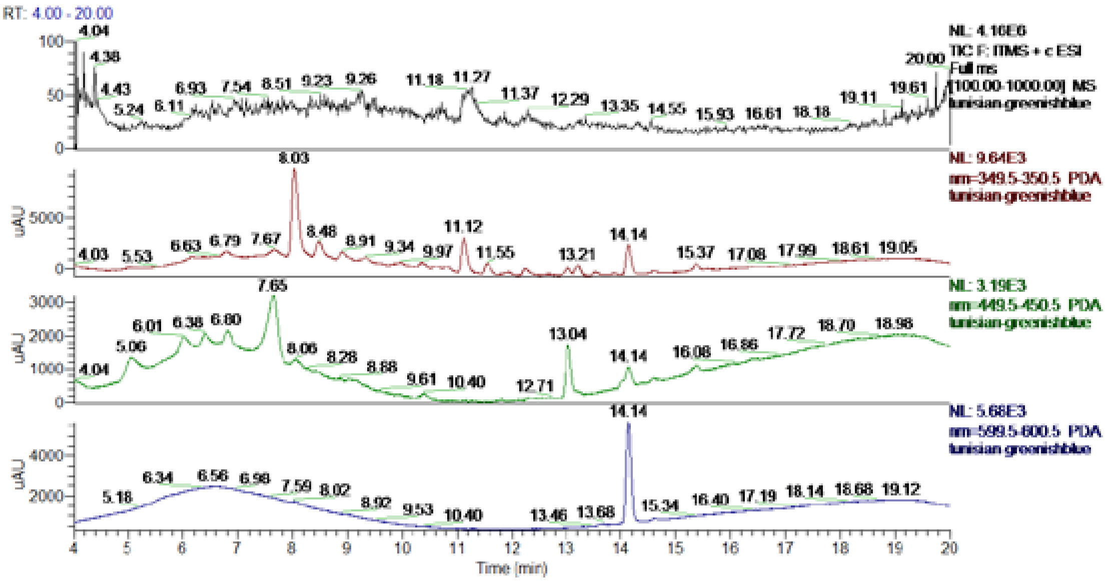
Note that after having dyed the wool, **the rest of the product (waste) can be reused either for coloring raw wool (to have darker colors during a second intervention), or for coloring other qualities of textiles (the satin silk and Cotton).**

In addition, **the rest of the plant products as well as the palm leaves are added to the debris of the components of the tree after the harvest (dates) to become after molding an organic fertilizer called "Compost", used in the context of new projects classified as '' green trades".**

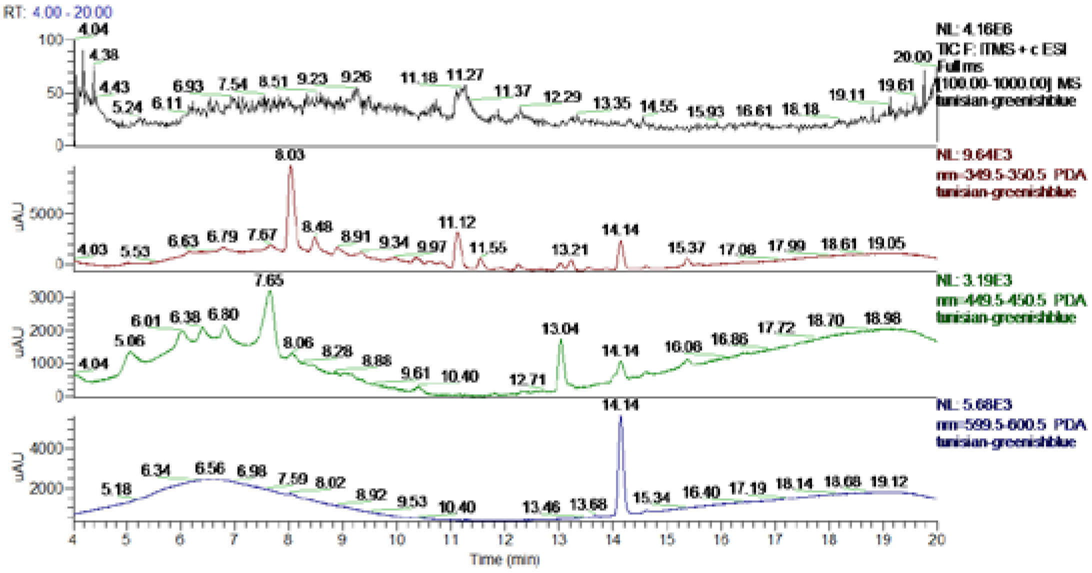
The diagrams shows below the analysis of a sample of a woven and colored hunbel with natural products made by the Textile Research and Analysis Laboratory at the Chinese Silk Museum, the names of the plant products are mentioned in each case as Tunisian dyes . The hunbel is a traditional outfit which is worn by young men before their marriage.



Black=tannin+madder



Blue=indigo+tannin



Red=madder

Figure 5. Analysis of natural Tunisian colors , extracted from natural plants.

3 MAIN PRINCIPLES AND IMPACTS IN LCA, LCSA AND LCC

3.1 LCA Definition

Life Cycle Assessment (LCA) is predominantly used to assess the environmental impacts of a system, but social LCA (S-LCA) and life cycle costing (LCC) are becoming established methods as well that allow for a holistic analysis of the potential implications of policy – and their integration into **life cycle sustainability assessment** (LCSA) .

These tools help us understand the main thresholds, how much of something should we produce (as opposed to looking at impact per unit production).

The 3E model is a scientific and rational model providing weighted 3E results: LCC focuses on economic burden, LCA reflects environmental impacts and energy consumption; finally, the 3E model integrates these three aspects simultaneously, as shown in Figure 6.

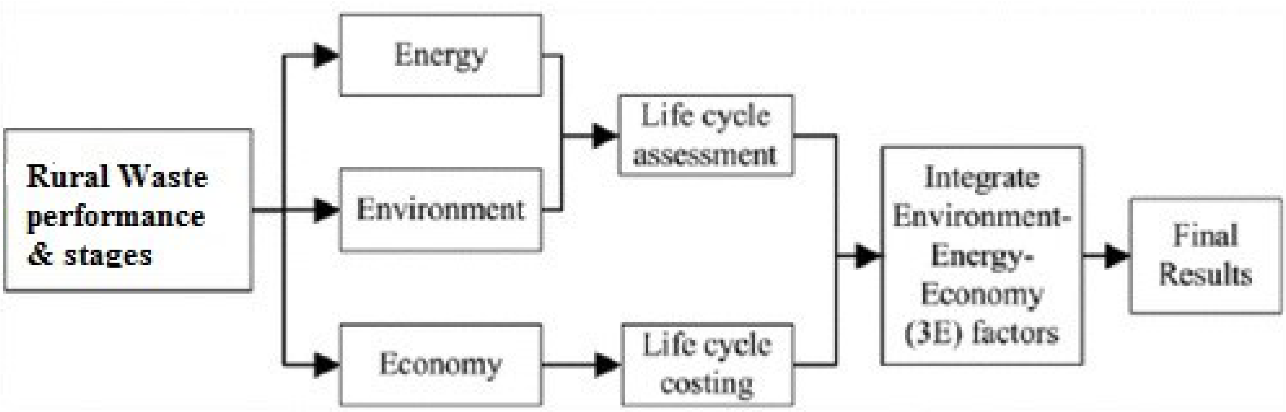


Figure 6. 3D model of A-WtE technologies. Source: Reich, 2005; Silvestre et al., 2013.

LCC is an excellent economic assessment tool. On the basis of whether environmental impacts are involved, LCC can be divided into traditional LCC and environmental LCC: Traditional LCC only focuses on monetary costs, while environmental LCC expresses environmental impacts in monetary units. Traditional LCC is often applied to waste treatment and combined with LCA to provide environmental and economic results, respectively; however, environmental LCC is still confronted with many difficulties, for example lack of market prices of emissions and authoritative method.

The 'not in my backyard' attitude is an impediment to WtE facilities; SLCA can reflect the social burden of WtE in quantitative term; according to SLCA results, WtE techniques provide positive effects on some social indicators; however, its methodology and application need to be further developed. The 3E model integrates both LCA and LCC methods and aggregates their results on 3E into one single comprehensive figure with a mathematical method for sustainable WtE conversion.

ELCA, LCC, SLCA and 3E models make sense for WtE techniques on respective aspects. However, compared with LCA, only few evaluations are conducted to WtE techniques by using extension methods, especially regarding advanced thermal WtE techniques. Besides, there are many other limitations mentioned in the review. Based on the reviewed literature, some recommendations can be made for further assessment of WtE techniques.

Life cycle assessments (LCA) describe a "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.". The life cycle includes "consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal." **The first stage of an LCA is to define the scope of the analysis**, which is dictated by the capacity and the goals of the analysis. **The second stage is an inventory analysis whereby "all the inputs and outputs in a product's life cycle**, beginning with what [the] product is composed of, where those materials come from, where they go, and the inputs and outputs related to those component materials during their lifetime" are examined.**The third stage is an impact analysis, or an examination of the environmental or other impacts, from all of the inputs and outputs** – without translating these impacts into costs. LCA is descriptive and serves the important purpose of mapping out systems in great detail across time, space, and actors. **The fourth stage is Interpretation**. The purpose of this is to: "Analyze results, reach conclusions, explain limitations and provide recommendations based on the findings of the preceding phases of the LCA and to report the results of the life-cycle interpretation in a transparent manner. Life-cycle interpretation is also intended to provide a readily understandable, complete and consistent presentation of the results of an LCA.

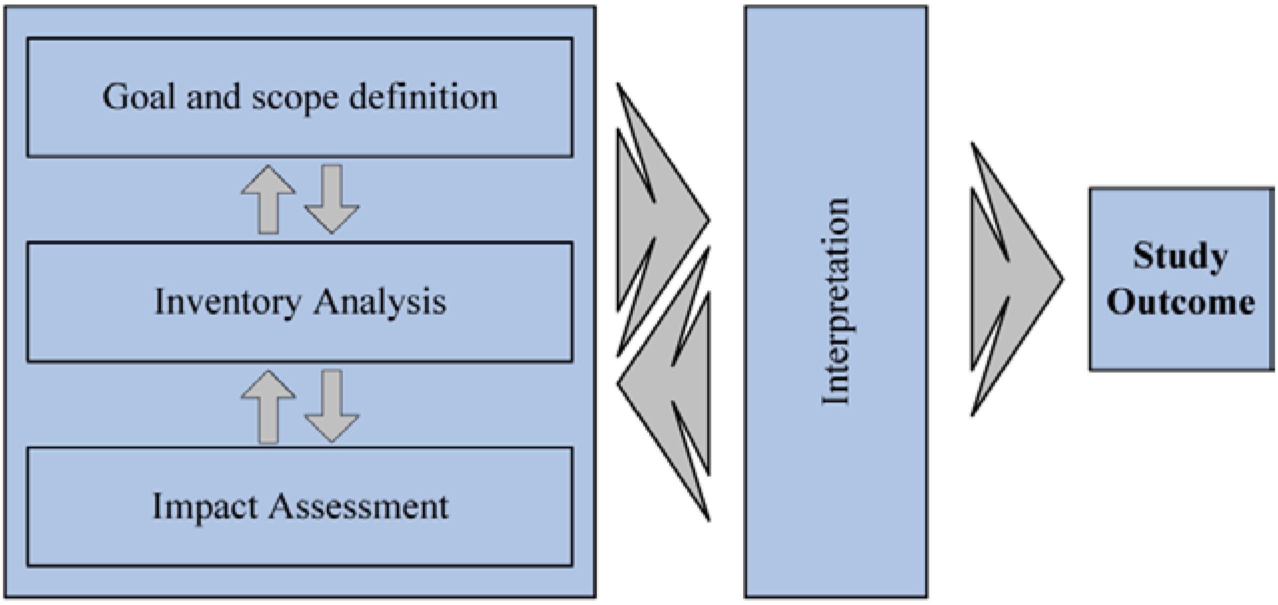


Figure 7. The 4 stages of Life cycle assessment. Source: Khasreen, M.M.; Banfill, P.F.G.; Menzies, G.F.[4]

3.2 Life cycle sustainability assessment (LCSA)

LCA is useful in quantifying the extraction of resources and emissions of a product system or process to **air, water, and land** and their associated impacts. LCA can be used to identify hotspots in the **life cycle** of a product or for different production processes of a product system.

In assessing sustainability on a life cycle basis, an integrated tool called **life cycle sustainability assessment (LCSA)** has been used.

4 Khasreen, M.M., Banfill, P.F.G., Menzies, G.F., 2009a. Life-cycle assessment and the environmental impact of buildings: a review. Sustainability 1, 674–701

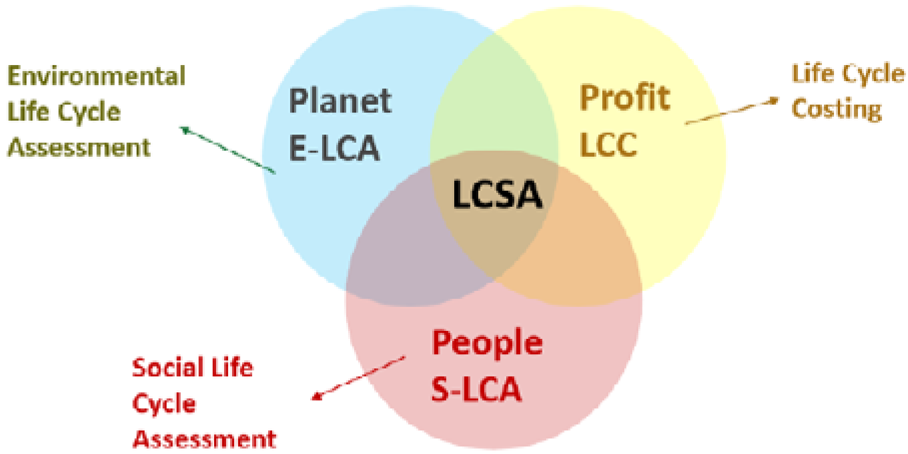


Figure 8. The main elements of LCSA. Source: : University of Utrech.[5]

The mentioned LCA tools (environmental, economic, and social) are integrated in LCSA to align with the three pillars of sustainability. From the first initiative of the German Oeko-Institut through product line analysis on to Kloepfer's formula in 2007, Finkbeiner et al. (2010) illustrated a strengthened LCSA as follows:

LCSA=LCA+LCC+SLCA

where: LCSA: life cycle sustainability assessment; LCA: life cycle assessment (**environmental**); LCC: life cycle costing (**economic**); SLCA, social life cycle assessment (**social**).

3.3 Cradle-to-Cradle Life cycle sustainability assessment (LCSA) as a holistic framework

A **Cradle-to-Cradle model** can be applied to many aspects of human society, and is related to **Life cycle sustainability assessment (LCSA)**. Additionally for instance the LCSA based model of the Eco-costs (analysed in LCC) can been designed to cope with analyses of recycle systems.

The phrase "cradle to cradle" itself was coined by Walter R. Stahel in the 1970s. The current model is based on a system of "lifecycle development" initiated by Michael Braungart and colleagues at the *Environmental Protection Encouragement Agency* (EPEA) in the 1990s and explored through the publication *A Technical Framework for Life-Cycle Assessment.*

5 Summary of Life Cycle Assessment , University of Utrecht, Academic Year 2016-2017. https://www.studocu.com/en/document/universiteit-utrecht/mw-life-cycle-assessment/summaries/lca-samenvatting-summary-life-cycle-assessment/961312/view

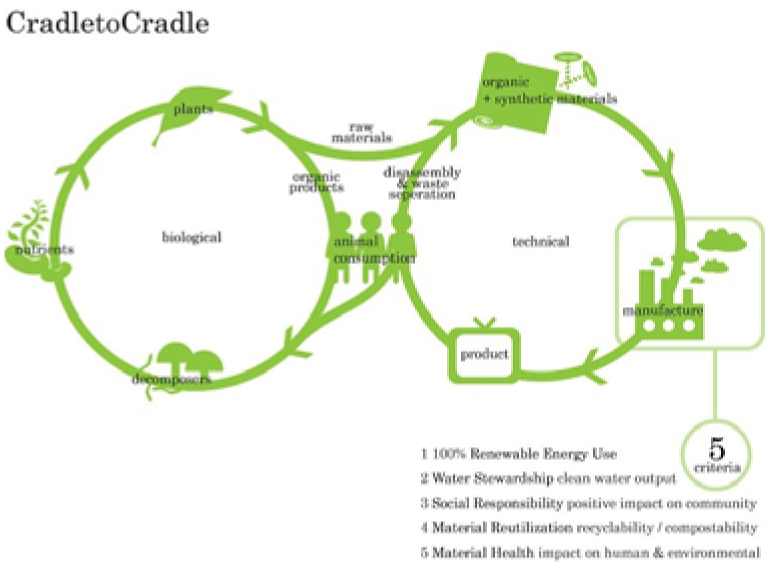


Figure 9. Biological and Technical Nutrients in the Cradle to Cradle Design Framework. Source: Zhiying.lim, 2012.

- **Technical nutrients** are basically inorganic or synthetic materials manufactured by humans—such as plastics and metals—that can be used many times over without any loss in quality, staying in a continuous cycle.
- **Biological nutrients** and materials are organic materials that can decompose into the natural environment, soil, water, etc. without affecting it in a negative way, providing food for bacteria and microbiological life

Cradle-to-Cradle is a **material reutilization, which is about recovery and recycling at the end of product life**, and it`s implying that the **C2C model is sustainable and considerate of life and future generations in the circular rural economy.**

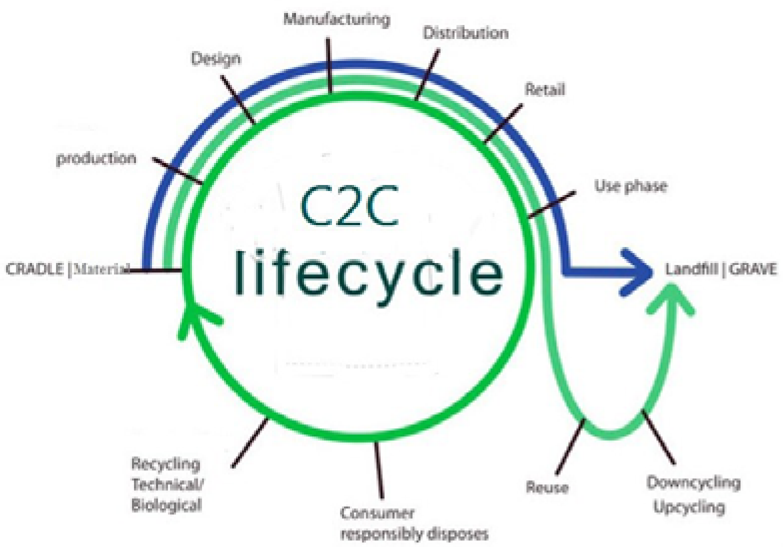


Figure 10. The Cradle-to-Cradle framework in rural economies (L2C & L2G). Source: dr Alison Gwilt,2013, adapted by the author.

3.4 Valorisation pathway analysis to extend the sustainable product lifecycle

3.4.1 Valorisation pathway diagram (sample)

The diagram below represent a **valorisation pathway model**. In order to better understand the logic of the valorisation pathway, D3.6. propose to follow a sample of the natural food ingredients.

Different scenarios (global economic situation, foreseeable environmental changes) are pushing farmers/producers to review the use of high yield crops and to focus **on the valorization of locally-adapted plants.**

This renewed interest is strengthened by the growing need of consumers for **functional foods with beneficial effects on human health and by the willingness to promote sustainable low-input agricultural practices exploiting local climate, soil, water.**

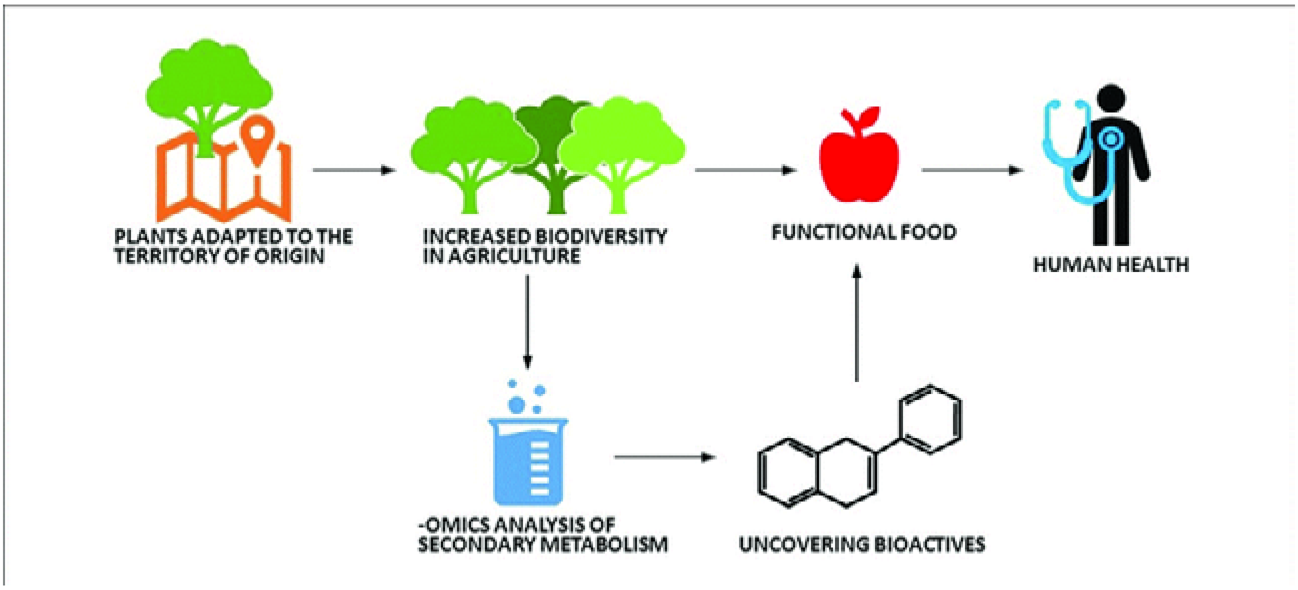


Figure 11. Valorisation pathway diagram of natural plants (medicinal herbs, spices, local ancient plant varieties). Source: Roberto Berni[6]

One segment of the food market garnering significant attention and experiencing strong consistent growth is the **"functional food" market.**

Functional food is a modified **food** that claims to improve health or well-being by providing benefit beyond that of the traditional nutrients it contains.

Functional food may include such items as *cereals, breads, beverages that are fortified with vitamins, some herbs, and nutraceuticals.*

Industry reports expect the global-functional food market to reach $92.3 billion by 2021 from $64.6 billion in 2016 at a CAGR of 7.4 percent.

6 Roberto Berni, Marco Romi, Claudio Cantini, Giampiero Cai: Functional Molecules in Locally-Adapted Crops: The Case Study of Tomatoes, Onions, and Sweet Cherry Fruits From Tuscany in Italy,

3.4.2 The LCSA framework allow a replication in any agricultural domain in LIVERUR and beyond: the Malta - case

The LCSA framework allow replication in another agricultural domain in LIVERUR project and beyond. The Malta pilot actions pushing further into **the functional food market** through internal innovation and external company investments (if possible later acquisitions) to increase revenue/ earnings growth.

LCSA on Natural Ingredients in Circular Living Lab Malta for instance can **be used for several purposes:**

- To give an overview on the environmental, social and economic impacts internally to each actors in the Circular Living Lab, for making **environmental, social and economic improvements** and thereby decreasing the environmental, social and economic negative impacts. The main goal is to achieve sustainability of products and process systems in the whole supply chain of the production.
- **In the product development phase** called eco-design, LCSA can be used for assessing the possible environmental, social and economic impacts **from a product that is under development**.
- **In marketing**, where the business development manager and Rural Living Lab business unit can promote and sell the own products with high environmental profile as well compared to other similar products on the market.
- To put pressure on the Living Lab's suppliers to make more environmentally and economically friendly **final products** (extracts, packaging, eco-labelling) to the global market.

The LCA results can this way be used to change parameters in the product or/and the production here of. The necessary data must be added, No Data (N/D) is only used in this sample. **The exact figures in Unit and Total raw of 5 Impact categories can be added in a later stage of the pilot project.**

Impact category	Unit	Total	Farming	Processing	Distribution	Use	End of life
Global warming	g CO_2-eq.	N/D	N/D	N/D	N/D	N/D	N/D
Acidification	g SO_2-eq.	N/D	N/D	N/D	N/D	N/D	N/D
Nutrient enrichment	g NO_3-eq.	N/D	N/D	N/D	N/D	N/D	N/D
Photochemical smog	g ethane eq.	N/D	N/D	N/D	N/D	N/D	N/D
Land use	m^2*year	N/D	N/D	N/D	N/D	N/D	N/D

Figure 12. A LCA Food database structure. Source: adapted from milk diary products of LCAfood Denmark.

LCA food database can be adapted for similar data on other agricultural products. 'Farming' includes all inputs and outputs from the farming process, like sowing, fodder, fertilizers and harvesting.

3.4.3 LCA in Tunisian sheep wool

Wool's life cycle begins on the Berber farms where wool grows naturally on sheep. After it leaves the farm it is cleaned and spun, then woven or knitted into carpets, rugs or other wool products. **Wool is resilient and long lasting, and readily recycled and reused.**

At the end of its useful life wool readily **biodegrades and returns to the earth.**

During the evaluation of the environmental performance of wool products, LCA typically measures the use of natural resources, greenhouse gas (GHG) emissions and other environmental impacts over a product's lifecycle.

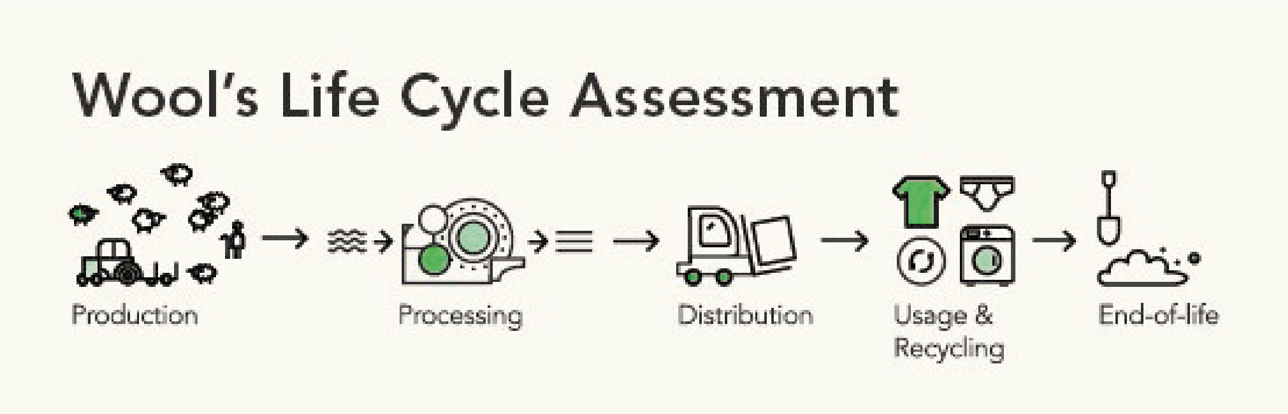


Figure 13. Wool`s Life Cycle Assessment. Source: IWTO, 2016.[7]

LCA on WOOL can help to identify the steps for action to increase efficiency in the wool supply chain, decrease negative impacts and accelerate environmental benefits, and to provide the data sought by brands, retailers and consumers.

IWTO's researchers are currently working to fill data gaps along the entire wool supply chain by working with early stage processors, spinning and weaving companies to measure and benchmark the wool industry's performance in areas such as water and energy use.

3.4.4 Product Life Extension assessment by Product Costs

3.4.4.1 Classified cost items in various production processes

In this stage, the cost items are classified by the following categories :

A) **initial costs** (i.e. planning, construction installation etc.)
B) **periodical maintenance costs** (replacement of spare parts)
C) **operational costs** (labour, energy, etc.)
D) **end of life disposal costs** (LE) **or residual value of the goods** (CE)

7 IWTO: International Wool Textile Organisation https://www.iwto.org/work/wool-LCA

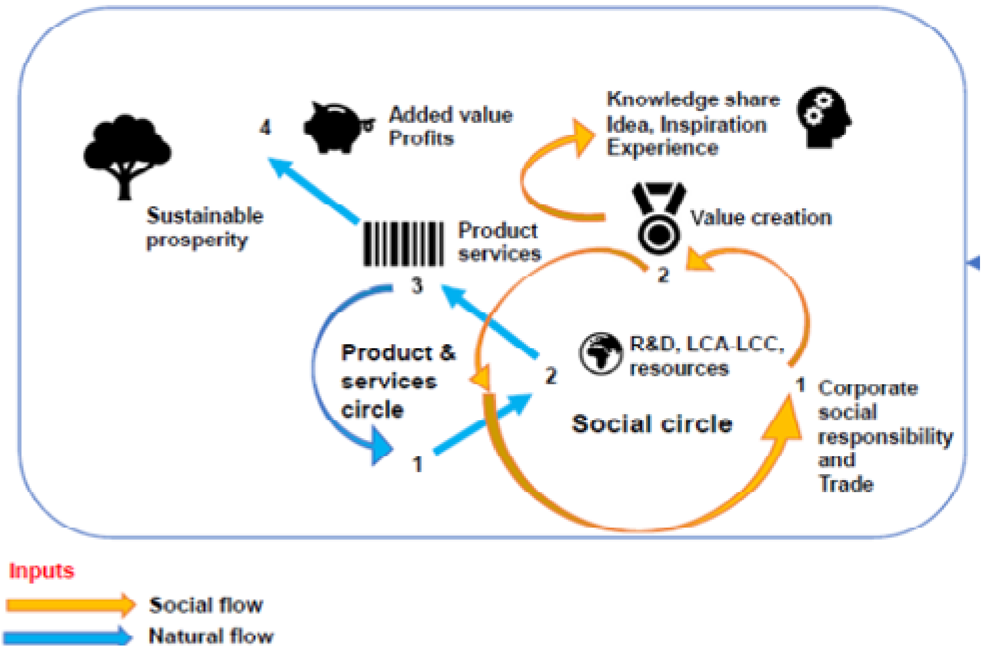


Figure 14. Rural Sustainable Food Value Chain. Source: author from LIVERUR DoW.

The input comes from **5 main stages of the main building blocks of materials and products.**

Stage (1-5) in LE and CE	Cost Type	Process	Data availability	Data Source
1.Farming stage	*Initial cost*	*Primary Raw Materials:* *Crop Selection,* *Seed Selection,*	*Available/ Estimated or N/A*	*Agribalyse* *Agri-footprint* *ARVI* *AusLCI* *Bioenergiedat* *Ecoinvent* *ELCD* *ESU World Food* *EuGeos'15804-IA* *European and Danish Input/ Output database* *exiobase* *GaBi* *LCA Food DK* *LC-Inventories.ch* *Industry data 2.0* *NEEDS* *Ökobaudat* *ProBas* *PSILCA* *Soca* *Social Hotspots* *Swiss Input/ Output Database* *US Life Cycle*
	Maintenance cost	*Irrigation*	*Available/ Estimated or N/A*	
	Operational costs - materials	*Land Preparation* *Seed Sowing* *Crop Growth* *Fertilizing* *Harvesting*	*Available/ Estimated or N/A*	
2. Processing materials stage	*Operational costs - materials*	*TBC*	*Available/ Estimated or N/A*	
	Operational costs -labour	*TBC*		
3.Manufacturing products stage (Lean Economy) /Remanufacture & refurbish stage (Circular Economy)	*Lifetime (LE)*	*TBC*	*Available/ Estimated or N/A*	
	Lifetime (CE)	*TBC*		

4.Distribution/ Market stage (LE)/ Reuse-Redistribute stage (CE)	*Initial cost (LE)*	*TBC*	*Available/ Estimated or N/A*	*Inventory Database USDA digital commons Internal database*
	Initial cost (LE)	*TBC*		
5.Use stage (LE)/ Maintenance & Share stage (CE)	*Maintenance cost (LE)*	*TBC*	*Available/ Estimated or N/A*	
	Maintenance cost (LE)	*TBC*		

Table 2. Table to Life Cycle Costing (LCC) Analyis in Linear vs Circular Economy. Source: modified from AgroCycle.[8]

3.4.4.2 Life cycle costing analysis of sheep wool fibre

The way we consume and what materials we prefer in our home interior has a huge impact on our environment. Wool is very common material in the textile industry for splurging a lot of fresh water in the various stages in treatment.

The wool has a major role to play in re-use and recycling.

Even wool garments do eventually come to the end of their lives. If not able to be recycled, it is worth noting that the wool fibre itself is naturally biodegradable. Part of the natural atmospheric carbon cycle, the carbon in **wool** comes from plants consumed by grazing sheep, rather than petrochemicals.

The Circular Rural Living Lab in Oudhref in South-Tunisia plan to build a full circular strategy in order to wove new products from upcycled wool materials. That means to extend the product lifecycle for re-use and transforms by-products from waste materials, useless or unwanted objects into Berber craft products and reuse the naturally coloured liquids into organic textile.

But one of the reasons for wool's value as a recyclable is its mature and established closed loop recycling route.

The Durability Factor

Due to the high quality and durability of the wool fibre, wool garments are inherently suitable for re-use and recycling. The average life of a wool garment is 2-10 years depending on use, compared to 2-3 years for a typical cotton or synthetic garment. This statistic, incidentally, is not without its own significance: surveys show that consumers use woollen products longer between washes due to wool's natural ability to keep itself clean or be refreshed by airing, which reduces the energy and water impacts of woollen garments.

This inherent resilience along with durability and high quality make wool a valuable raw material.

The Sustainability Equation

Given wool's propensity for recycling and established pathways, wool presents a substantial commercial opportunity for take-back schemes or other collection innovations.

8 AgroCycle: Sustainable techno-economic solutions for the agricultural value chain, H2020 project. http://www.agrocycle.eu

Garment collection rates in many developed countries have already substantially risen, driven by greater environmental awareness. With the advancing traction of the concept of the circular economy, opportunities for further development in this area are set to increase.

Moving Towards a Circular Economy

As the circular economy model is gaining ground, recovery and recycling of materials is a central element of the business model. Therefore, it is important for the wool industry to provide up-to-date research and fill in existing data gaps in order to back up this part of wool's sustainability story.

"Recycling is an ideal environmental option for wool products before they finally biodegrade at the end of life." - says IWTO President Peter Ackroyd.

Closing the Loop

Even wool garments do eventually come to the end of their lives. If not able to be recycled, it is worth noting that the wool fibre itself is naturally biodegradable.

Part of the natural atmospheric carbon cycle, the carbon in wool comes from plants consumed by grazing sheep, rather than petrochemicals. Because of this, wool easily decomposes at end of life, releasing its valuable nutrients into the ground in a relatively short period, unlike synthetics. In the context of recycling, wool truly closes the loop – bringing yet another advantage to choosing wool.

Environmental, social and economic aspects in the life cycle costing of sheep wool.

Figure 15 shows the general structure of a livestock farm completed by **social boundaries** (*manpower units, relationships with rural areas, tourism and traditional cultural aspects, etc.*) and **economic boundaries** (*cost and revenues, taxes and national subventions, local economic advantages of added values, general willingness to pay for environmental goods and ecosystem services*).

Integrative analysis can be analysed as the combination of **Life cycle sustainability assessment (LCSA), Social life cycle assessment (SLCA) and Life Cycle Costing (LCC).** This aspect of the system can represent a multi-functionality and it has important implication on the allocated methods by sharing of resources, inputs and impacts.

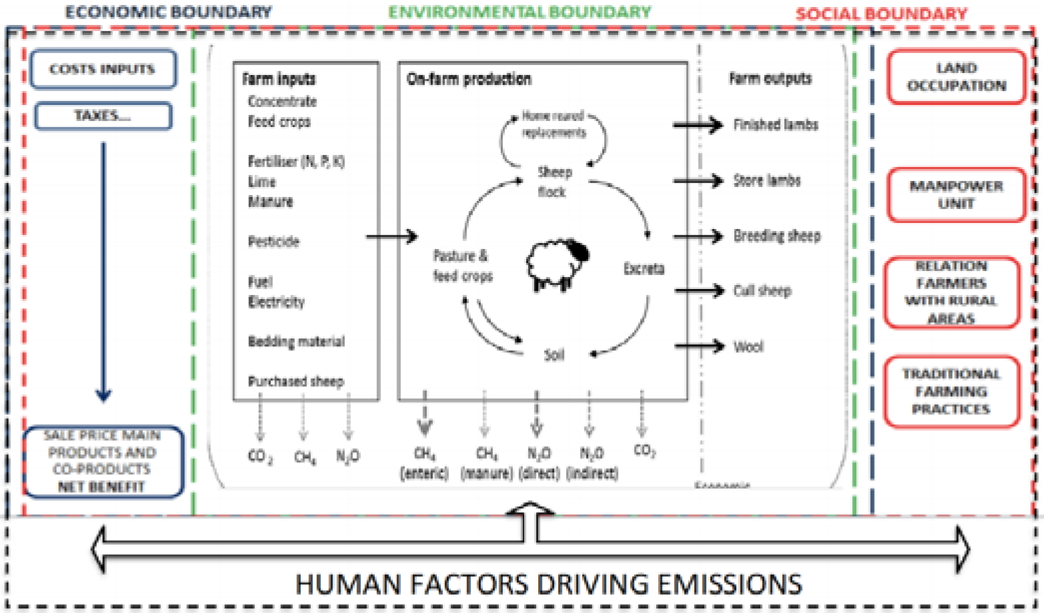


Figure 15. Environmental impacts of sheep wool production with economic and social aspects (Adapted from Jones et al., 2014 and Batalla et al., 2014)

3.5 LCSA integration in the Circular Rural Living Lab framework

The LCSA as a sustainability evaluation tool correspond well to the Circular Rural Living Lab methodology, because A) **the 01-04 steps of LCA follow an iterative process** and B) **integrate the Environmental – Socio-Economic Impacts** through C) **LCA + S-LCA + LCC= LCSA**. The combination of different assessment methods and merging their results to a comprehesive Life Cycle Sustainable Assessment would ensure a D) **contribution of circular approaches through the 4 main steps in the Rural Living Lab framework**. By the collection of basic DATA from 19 partners in T3.6 cover the Step 01-02 in both layers (LCA and Living Labs as well. (See. Chapter 1.2). **The LCA for sustainable production in rural areas is proposed to be measured during and after the pilot actions (WP5 , WP6 and WP7) in order to understand how to pay more attention to the social, economic, and environmental aspects of sustainability.**

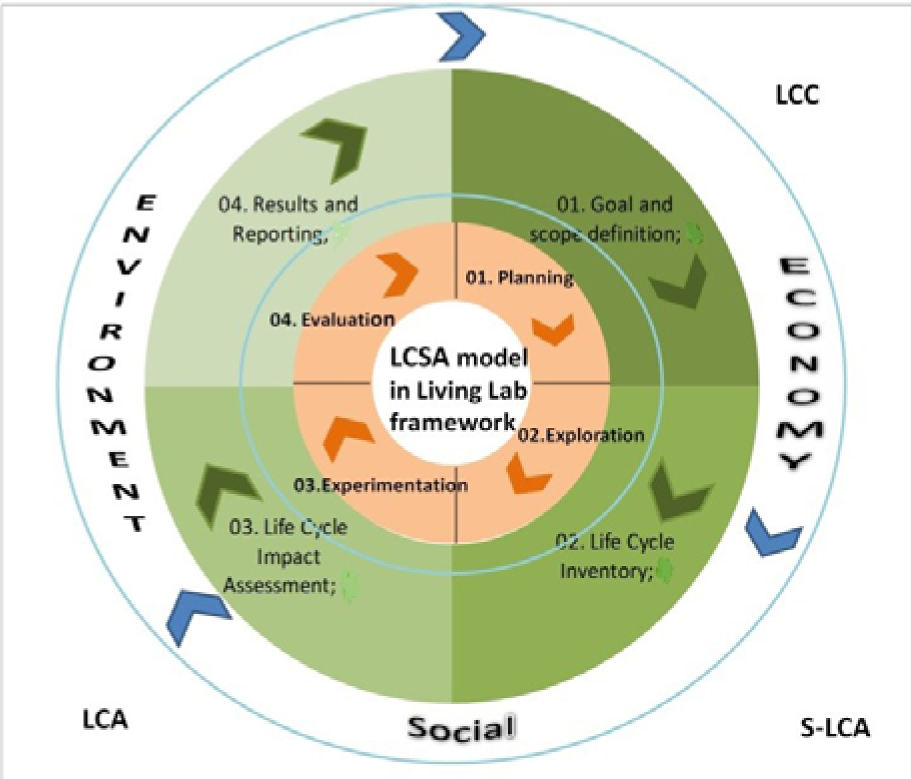


Figure 16. LCSA model integration into Living Lab framework, by the author.

4 CASE STUDIES OF AGRI FOOTPRINTS (No.1-4)

Four illustrative Case studies were selected, from rural waste to waste productivity, in order to demonstrate the recyclability , sustainability and extended life cyle of the redesigned products and processes in various domains and terroritories.

Case Study 1. Coco Hill Forest – Permaculture & Organic Agroforestry and Green Therapy (Barbados)

Tourism is a vital economic sector for many countries and the CE has a growing importance for the marketing of eco-tourism destinations. As part of a movement towards sustainable tourism in the **Caribbean**, eco-resorts are using circular agriculture to reduce their environmental impact and make the most of local produce.

The Ocean Spray eco-resort in Barbados uses the tropical rainforests surrounding it as the inspiration for a CE business based on agroforestry and permaculture, even inviting guests to forage for food as part of their experience. The hotel covers over 21 ha of terraces with over 80 different types of fruit trees and edible plants including coconuts, bananas, cocoa, coffee and pineapples, in addition to a flock of free-range chickens.

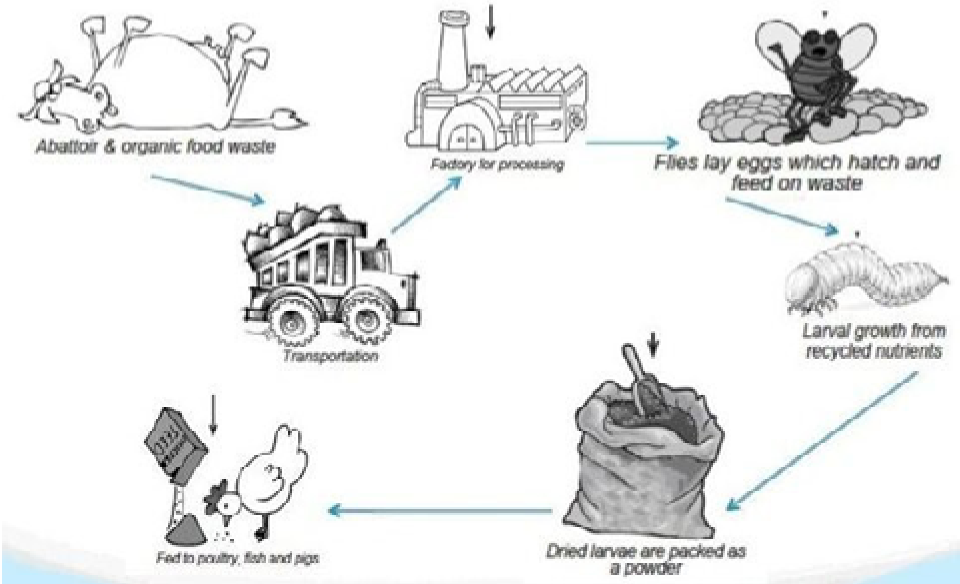
Importantly, the resort strives to be zero-waste, as owner Mahmood Patel explains: “We are focused on taking land that has been undeveloped for over 100 years and are turning it into a food forest. We strive to keep everything in a cycle. We take all of our leaves and cuttings and put them back into the ground. We take dry coconut husks, put them in a chipper and bury them. We use the chicken and the goat manure as fertiliser. We take the eggshells, the coffee grinds and ‘green stuff’ from the restaurant and send them back up to the forest to fertilise the soil.”

https://www.forbes.com/sites/daphneewingchow/2019/03/10/agro-forestry-project-brings-blue-green-therapy-to-barbados/

https://www.vice.com/en_ca/article/vbz9qy/barbados-farming-movement

https://www.youtube.com/watch?reload=9&v=6U-5pMxpJoE

Case study 2. Going Green: Agriprotein fishmeal from South Africa



In South Africa, multinational company AgriProtein has tackled organic waste by using insects to create 100% organic fish and animal feed, oils and soil fertiliser. The company breeds black soldier flies, the larvae of which rapidly break down organic waste while increasing their weight over 200 times in a 10-day period. The core product is made from dried and defatted insect larvae that are ground into a high-protein meal suitable for a wide range of farmed fish and livestock. Additionally, the oil extracted from the fat of whole dried larvae can be blended with a variety of animal feeds. Finally, the larval residue is blended with compost to create a fertile soil enrichment.

These multiple output streams ensure that AgriProtein produces little waste during manufacturing and promotes sustainable farming practices. The company currently has farms in Cape Town, Durban and Johannesburg with plans to expand its business at a rate of two standard factories a month across the continent. Each factory will be capable of processing 250 t of waste per day, from which they can create 5,000 t of meal and 2,000 t of oil per year.

Circular agriculture has the potential to be a flexible system that can be adapted for any location or sector. With an increasing need to reduce waste and use limited resources efficiently to feed an ever-growing world population, the need for a more sustainable approach is critical. Creating a CE can not only maximise the allocation of limited resources without further harming the environment, but also creates a more efficient economic system, with ultimately more food created per unit input.

https://edition.cnn.com/videos/tv/2019/12/02/going-green-agriprotein-fishmeal-south-africa.cnn

https://agriprotein.com

Case study 3. Olive briquette

Today and due to environmental awareness, people have turned to other types of alternative fuels to oil such as biomass, a renewable energy source which is usually plant matter or forest residue, or even municipal solid waste.

Another source of biomass can be marc, the solid waste that is left by the olive grain during the process of extracting olive oil. When the marc is processed by refineries to obtain second category oil, a solid residue is also produced, the pomace wood.

In fact, this type of fuel is not so new, since being abundant in Greece, Spain and other large producers of olive oil, it has been used as fuel in oil mills and other factories for years . But now people are starting to realize that it can be used to heat homes, hotels and even entire cities.

Pomace wood does not have the calorific value of oil, but it costs only a third of its price and it is considered ecological because it does not emit sulfur when burned.

But we haven't finished yet; a by-product of the combustion of pomace wood is marc powder. This powder can be turned to briquettes the size of a roll of coins and these briquettes are now widely used in barbecues and restaurants: they can replace charcoal since they ignite immediately, there is no no sparks flying around and no ugly smells.

The few companies that make briquettes in Europe sell them to restaurants in Sweden, Japan and elsewhere. But the most important fact is that the pomace wood and the pomace powder comes from olive pits and that no tree is cut and wasted, which gives it an environmentally friendly character. Undoubtedly, the humble olive is a little treasure from which we are still learning.

http://www.bioenergy-machine.com/make-olive-Pomace-into-pellets-or-briquettes.html
https://www.olivebriq.ca/products
https://www.youtube.com/watch?v=RdwP4wueHA0

Case study 4. Reusage/recyclage of Berber wool carpet (dar margoum) from solid and liquid waste through natural colorization

Berbers were the original inhabitants in the North of Africa and for thousands of years they were completely isolated from any external influence. “Berber” proceeds from the word “barbarian”, the name Romans used to refer to them. However, they call themselves as “amazigh” which means “free men”. They do not form a nation or a state although they still claim for their rights as an independent culture and spread across the Maghreb (Mauritania, Morocco, Algeria, Libya, Tunisia and Western Sahara).

From time immemorial, Tunisian Berber rural people and shepherds based their economy on sheep and their wool used by women to weave rugs, which fully reflect the importance of wool in every aspect of Berbers life. The rugs are artisanal handmade with sheep wool using simple wood looms either vertical or horizontal, laid on the floor. The loom size restricted the rug wide to 2 meters approximately; the size needed by a family to sleep, and it is very rare to find an old rug which is not long and quite narrow.

Culture and tradition within every Berber community are very different among regions. So and depending on the tribe, rugs may show different styles, colors and weave techniques even belonging to the same generic type.

In terms of design, the Oudref rugs combine abstract and irregular patterns with around 70 Berber symbols. They frequently decorated with other materials such as cotton and wool dyed with vegetal colours or recycled fabric threads of different colour.

https://www.picuki.com/tag/LIVERUR
https://www.picuki.com/media/2166225007944259084
https://www.picuki.com/media/1988547537339247652

CONCLUSIONS

After to define the potential pathway from linear to circular economy, **LIVERUR** project propose new economic models, which would based on the assumption that the value of rural products, raw materials and resources in the rural economies are to be maintained for as long as possible to ultimately minimalize the solid and liquid waste generation. Efficient use of resources is the priority of the circular rural economies, therefore **LIVERUR** project partners are working hard on the circular modes and related methodologies, like LCA, LCSA and LCC in the extension of the product lifecycles.

In the main concept of **LIVERUR**, raw materials are expected to be recycled in the targeted **LIVERUR** pilot actions by **closing the product life cycle** and transition from the linear economy model to the **closed circuit model** (production-use-use of waste as raw material in the next production).

The pathway to the new European Green Deal[1], to build a new circular roadmap for the EU, starts with Europe's communities. **LIVERUR** project limits the attention to the rural and peri-urban communities. The **3E model** (environment-economy-energy) is well incorporated into the main **LIVERUR** concept in oder **to minimise the environmental negative impacts, but don`t forget the social impacts.**

And yes, **LIVERUR** corresponds well to the main expectations of the European Green Deal goals and roadmap:

"The area under organic farming will also need to increase in Europe. The EU needs to develop innovative ways to protect harvests from pests and diseases and to consider the potential role of new innovative techniques to improve the sustainability of the food system, while ensuring that they are safe." (extract from the European Green Deal communication).

Figure 17. Circular Economy model with the main 3 benefits. Source: EC booklet of DG Research and Innovation 2017.

1 The European Green Deal communication by the European Council, EP, EC , Committee of the Regions, 2019 https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf

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ANNEXES

ANNEX 1: Guideline to Table 1: Synthesis table of rural waste & resources in circular mode within 19 LIVERUR pilot actions

All Partners were requested to fill up the Table No 1.

Step 1. . Please select the types of waste in your circular rural pilot action

Type of waste in your pilot action	(Take your choice by X)
Solid waste	
Liquid waste	

The definition of the main 2 types of rural waste aste can be read on Page 9.

More link: https://www.bafu.admin.ch/bafu/en/home/topics/waste/guide-to-waste-a-z/biodegradable-waste/types-of-waste/agricultural-waste.html

Step 2. Please underline the most relevant sector (s) - (several options are possible)

Sector(s) (Underline the best fit)	
Horticultural	Tree tranks & branches
	Plant parts
	Trimmings (leaves etc.)
Agricultural	Livestock
Agricultural	Crops
Agricultural	Agri-food
Waste water	Domestic waste water Industrial waste water

The definition of the proposed 3 sectors can be read on Page 9 and on the weblink: http://vikaspedia.in/energy/environment/waste-management/solid-and-liquid-waste-management-in-rural-areas

Circular modes in sustainable rural supply chain (Underline the best fit)
Redesign
Recollect the raw materials
Remanufacturing
Reuse /Recycling
Redistribute
Remarketing
Recommercialize

About the main elements of the circular modes in sustainable rural supply chain can be read in Mowing towards the Circular Economy on Page 62/169
http://files.nesc.ie/nesc_reports/en/144_Moving_Towards_the_Circular_Economy.pdf

Main intervention areas in life cycle assessment (Take your choice by X)			
C L A S S I C A L	E N V I R O N M E N T A L	S O C I A L	E N E R G Y

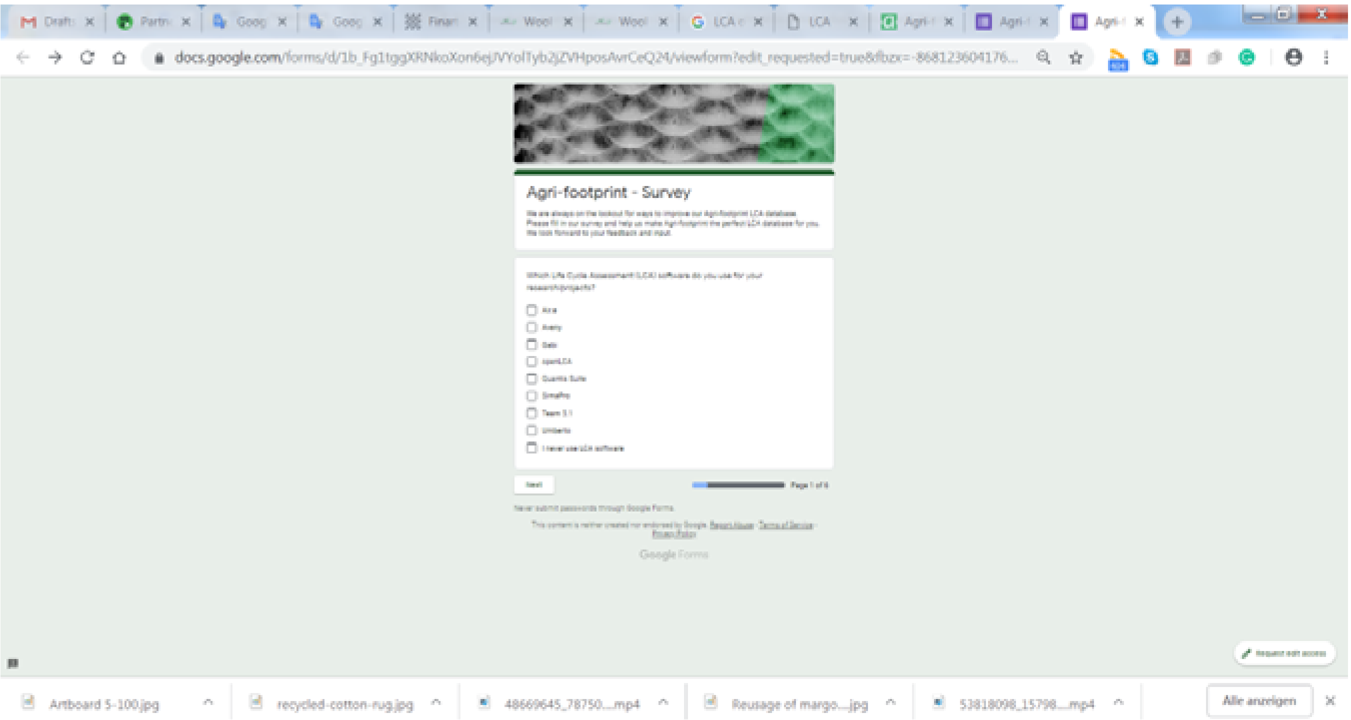
Definition of Classical LCA, e-LCA , S-LCA or LCC can be read on Page 4 of D3.6. and also on THE APPLICATION OF LIFE CYCLE ASSESSMENT IN CIRCULAR ECONOMY, written by K.Toth Szia on
https://pdfs.semanticscholar.org/b8a3/de970ac8ac21c9715b6fe1fa086a60227c81.pdf

A Sample to fill the sections by TRA (Malta):

5	TRA (MT) Malta/ Birkirkara	*Circular Rural Living Lab Malta*	Solid waste	X	Horticultural	Tree tranks & branches	**Redesign**	CLASSICAL	ENVIRONMENTAL	SOCIAL	ENERGY
						Plant parts	**Recollect the raw materials**				
						Trimmings (leaves etc.)	**Remanufacturing**				
					Agricultural	livestock	**Reuse/Recycling**				
					Agricultural	**Crops**	**Redistribute**				
					Agricultural	**Agri-food**	**Remarketing**		X	X	
			Liquid waste	X	Waste wate	**Domestic waste wate** Industrial Waste wate	**Recommercialize**				

ANNEX 2: Agri-footprint Database Survey for LCA, provided by www.agri-footprint.com

Step 1.



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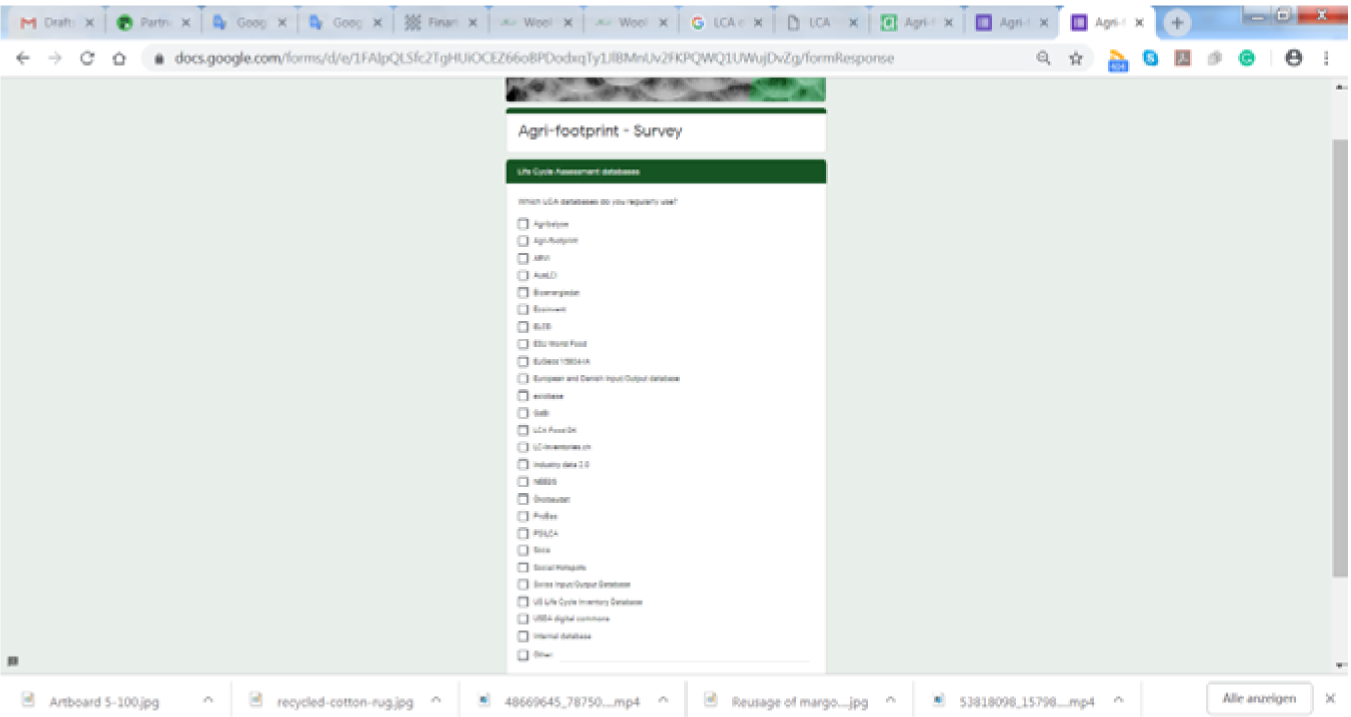

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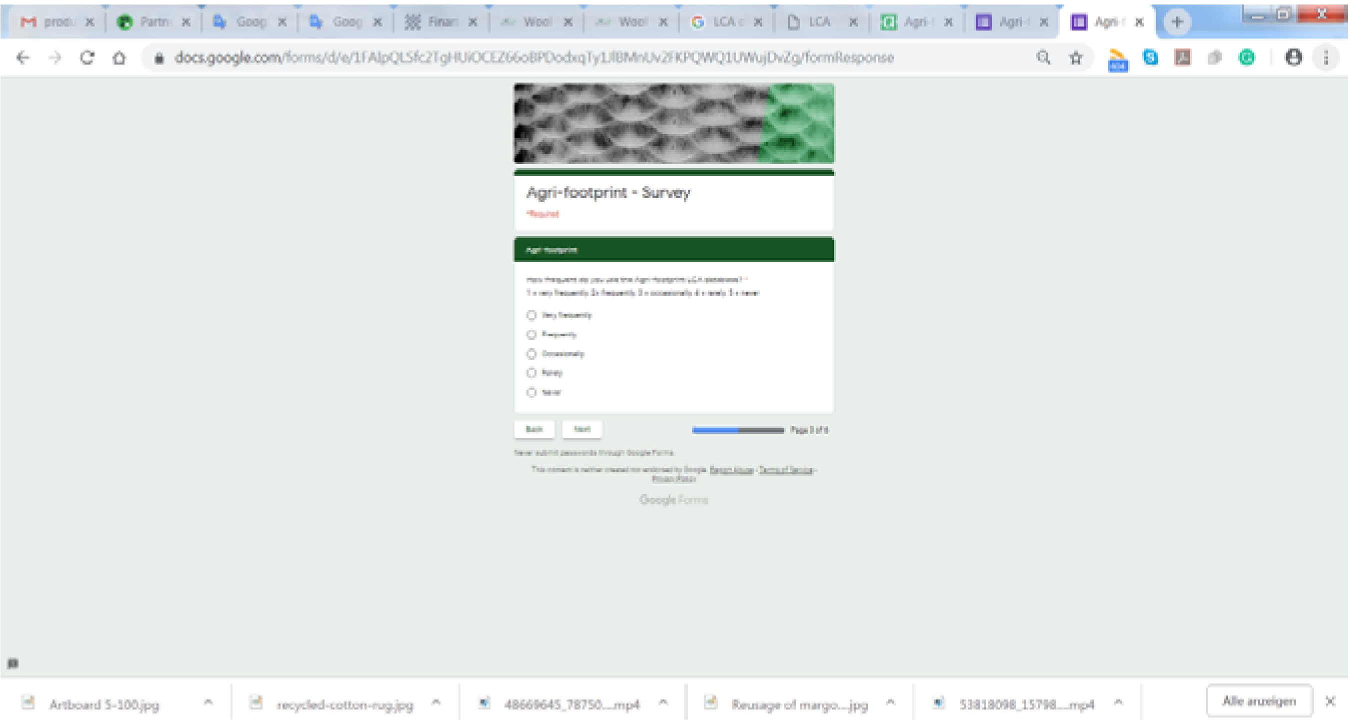
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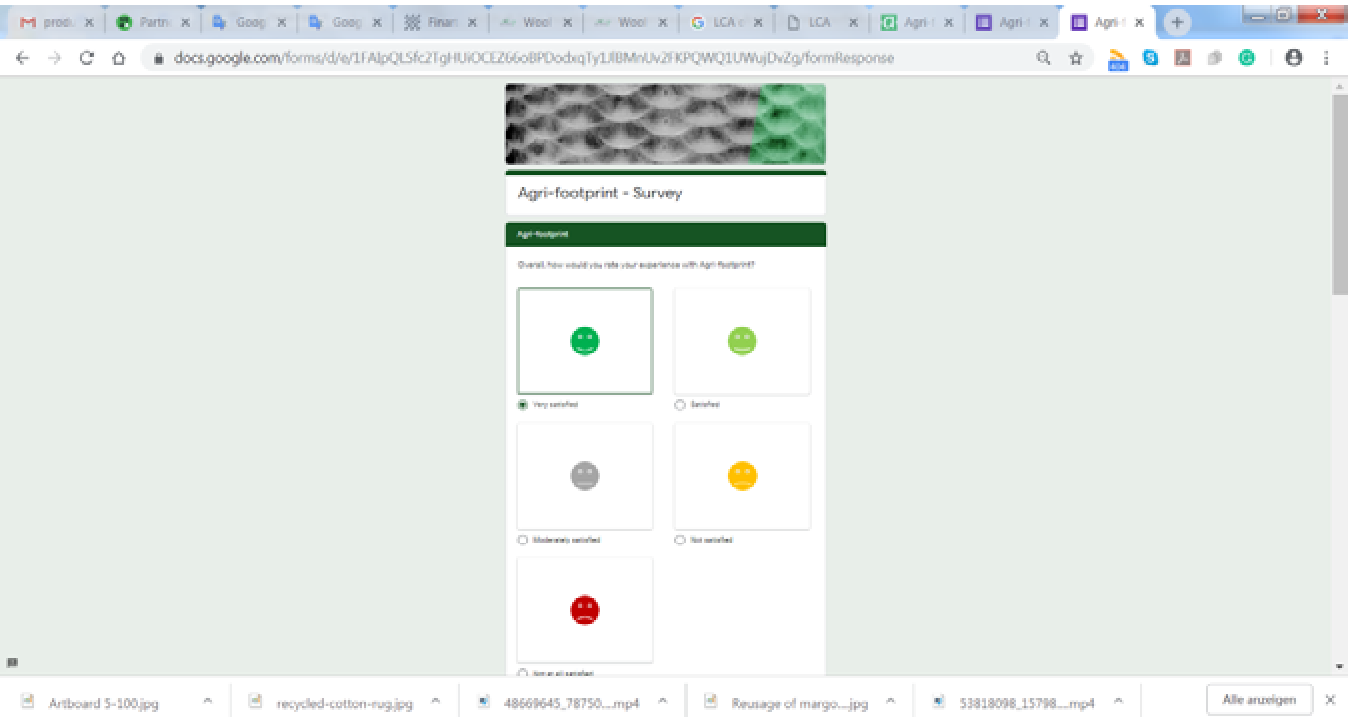
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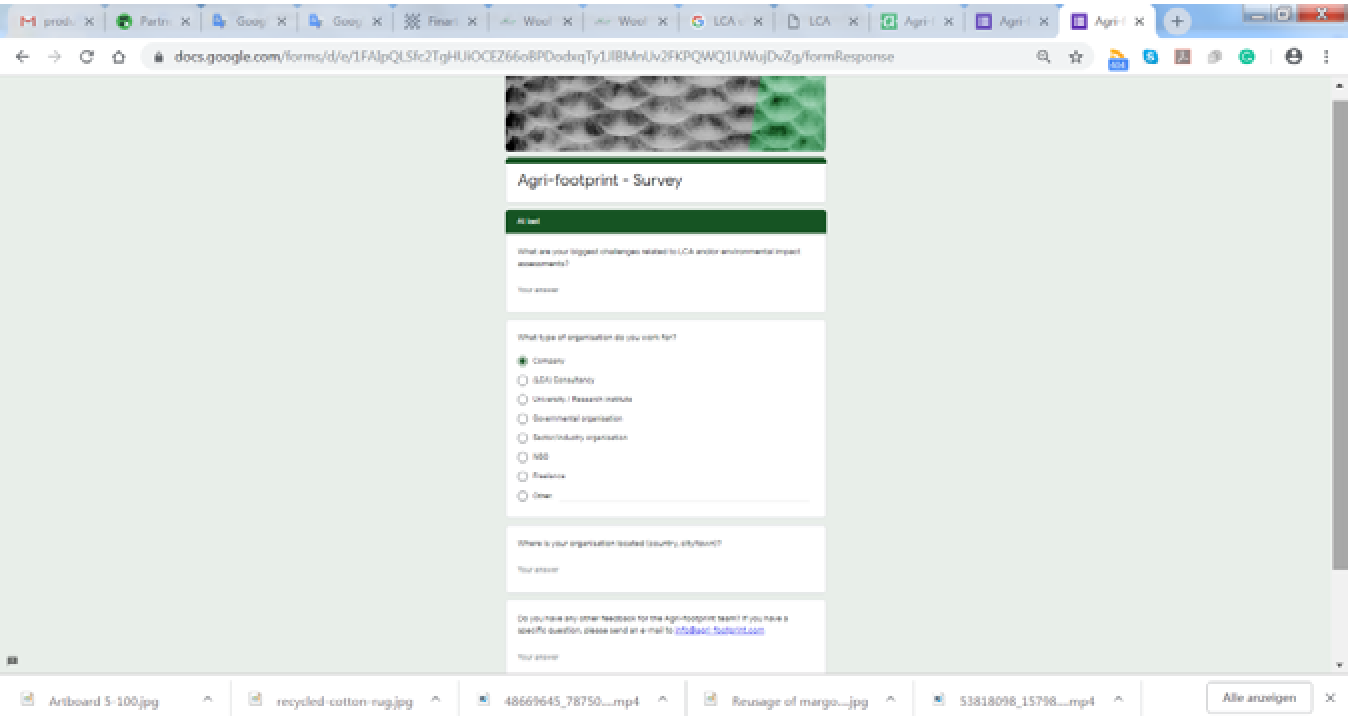
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recycled-cotton-rug.jpg
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Photo 1. Reuse of Plant Waste 1. In Oudhref Tunisia.

Photo 2. Reuse of plant waste 2 in Oudhref, Tunisia.