FuturEnzyme
WP7: Formulation and manufacturing of consumer products: sustainability and environmental assestments

Meeting #2

12M annual meeting

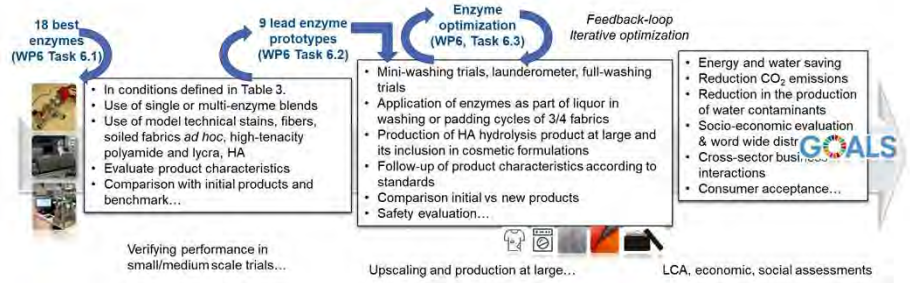
05/31 – 06/01/2022

Project funded by the European Union's Horizon 2020
Research and Innovation Programme under grant agreement No [101000327]

Work package number [9]	WP7	Lead beneficiary [10]	10 - CLIB
Work package title	Formulation and manufacturing of consumer products: sustainability and environmental assessments		
Start month	1	End month	48

Objectives

The main objective of WP7 is upscaling the appropriately dimensioned trials for i) integrating the best enzymes as ingredients for leading premium liquid detergents and/or unit dose caps products, ii) producing textiles with different requirements regarding pretreatment and finishing, and iii) for producing HA products of defined size and integrating them into leading cosmetic products. The idea is to start with specific real-life products already stablished worldwide by the 3 manufacturers, and making them greener, more innovative and more functional. In the detergent field, enzymes will be integrated into leading liquid detergent and or unit dose caps to obtain a detergent with more sustainable raw material compositions and less footprint impact in energy and water consumption during a low temperature wash process. In the textile field, enzymes will be used to develop an environmental-friendly process to improve the dyeability and washability of, and introduce new functionalities and characteristics to, synthetic fibers, and for hygenisation effects. In the cosmetic field, the aim is to identify enzymes that can degrade highly insoluble HA at low temperatures to produce in aqueous systems cosmeceutical ingredients of defined size, significantly reducing the energy consumption associated with the process and the use of solvents; this ingredient will bring new functionalities and characteristics to the cosmetic products into which they will be integrated. For extensive details see Section 1.4 and Table 3 (p. 14 Part B). To achieve these objectives, the different enzyme formulations (the ones produced in Task 6.1 with the 18 best pre-lead enzymes, and the ones in Tasks 6.2 and 6.2 with the 9 lead enzymes), will be tested, hand-in-hand, with small to real validation pilot trials, depending on sample size and product to develop. The following sub-objectives will be considered:



WP7 leader CLIB will organize regular task group meetings (planned every 6 months, and ad hoc if necessary, physical or online) between the contributors to each task. CLIB will serve as neutral mediator, ensuring information flow and providing minutes as well as decided action reports. It will be essential to ensure efficient collaboration in the WP7 and to streamline feedback between the enzyme manufacturing in WP6 and product testing and prototyping in WP7. This is to make sure that there is an iteration loop between the design of small-scale tests and their results at the academic partners, and the formulation and product design by the industry partners. In each task, partners will jointly develop criteria to decide which enzymes to select for inclusion in the product formulation (parameters will include e.g. expression, enzyme performance, stability, formulation, LCA performance, and cost). The aim is to align the research towards marketable end products and processes.

Participation per Partner

Partner number and short name	WP7 effort
1 - CSIC	5.00
6 - IST ID	22.00
8 - ITB	9.00
10 - CLIB	11.00
12 - Bio_Ch	7.00
13 - SCHOELLER	15.00
14 - HENKEL	7.00
15 - EVO	7.00
Total	83.00

Description of work and role of partners

WP7 - Formulation and manufacturing of consumer products: sustainability and environmental assessments
[Months: 1-48]
CLIB, CSIC, IST ID, ITB, Bio_Ch, SCHOELLER , HENKEL, EVO

Task 7.1 Pre-industrial validations: formulation of real-life and solution-oriented detergents M20-M48
Lead partner – HENKEL
Participants: CSIC, IST-ID, BIO_CH, CLIB

Task 7.2 Pre-industrial validations: formulation of real-life and solution-oriented textiles M20-M48
Lead partner – SCHOELLER
Participants: CSIC, IST-ID, BIO_CH, CLIB

Task 7.4 LCA assessments: detergent, textile and cosmetic products M1-M48
Lead partner – ITB
Participants: CSIC, HENKEL, SCHOELLER, EVO

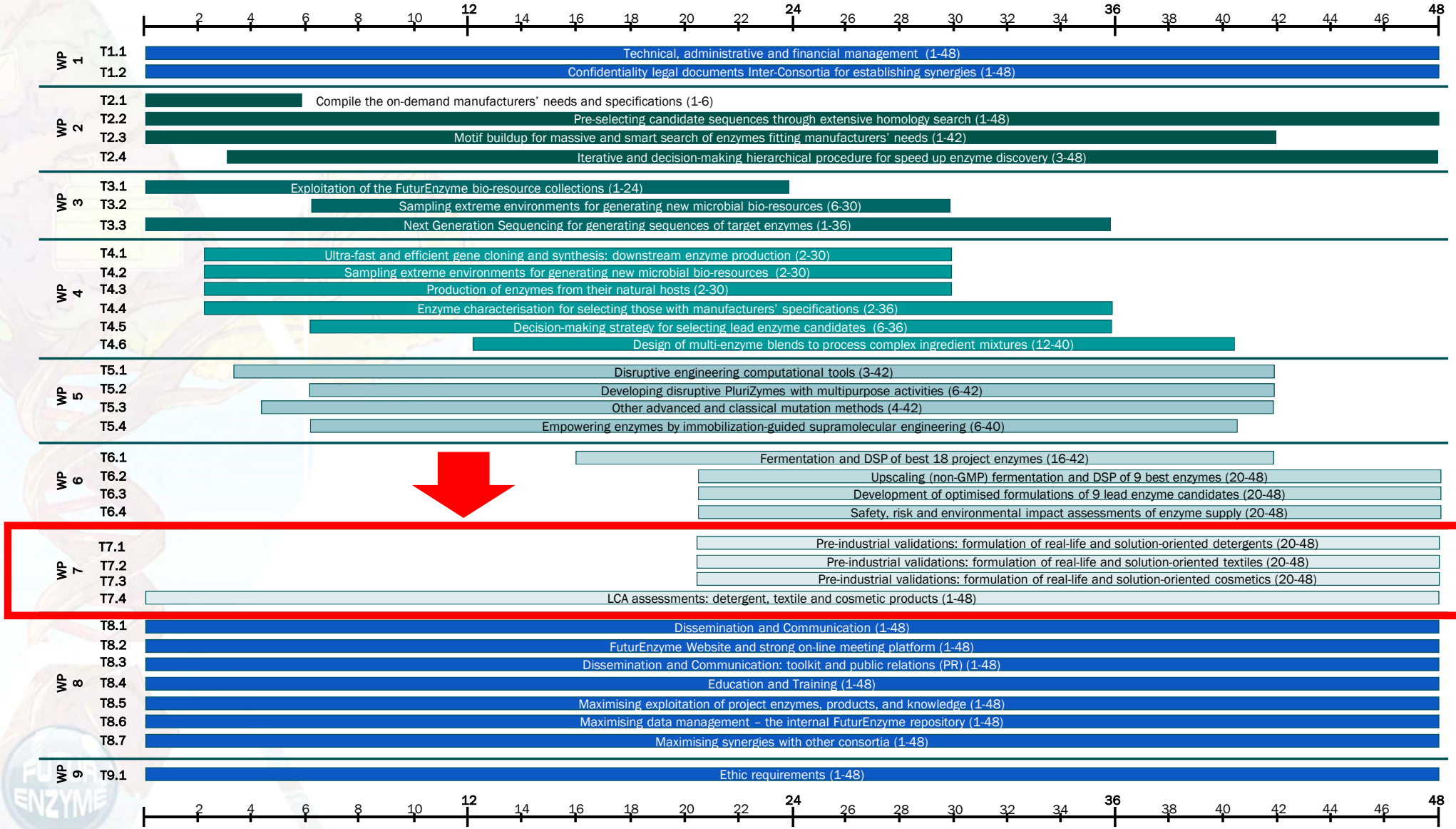
Task 7.3 Pre-industrial validations: formulation of real-life and solution-oriented cosmetics M20-M48
Lead partner – EVO
Participants: CSIC, IST-ID, BIO_CH, CLIB

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D7.1	Report on small/medium validation trials of 18 best pre-selected enzymes	1 - CSIC	Report	Confidential, only for members of the consortium (including the Commission Services)	34
D7.2	A leading liquid and a unit dose cap detergent product with new enzymes integrated	14 - HENKEL	Demonstrator	Confidential, only for members of the consortium (including the Commission Services)	46
D7.3	3-4 Enzymatically functionalised leading textiles in more than DIN A4 size	13 - SCHOELLER	Demonstrator	Confidential, only for members of the consortium (including the Commission Services)	46
D7.4	A leading cosmetic formulation with an enzyme-based HA-hydrolysis product integrated	15 - EVO	Demonstrator	Confidential, only for members of the consortium (including the Commission Services)	46
D7.5	LCA report of the 3 real-life products	8 - ITB	Report	Confidential, only for members of the consortium (including the Commission Services)	48
D7.6	Report on project results and lessons learned	10 - CLIB	Report	Public	48

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS22	First round of laundry tests completed	14 - HENKEL	26	Report available - this milestone will attest the completion and outcomes of the first laundry tests.
MS23	First round of textile tests completed	13 - SCHOELLER	26	Report available - this milestone will attest the completion and outcomes of the first textile tests.
MS24	First tests for hydrolysis of hyaluronic acid (HAh)	1 - CSIC	26	Report available - this milestone will attest the completion and outcomes of the first enzymatic tests for hydrolysing hyaluronic acid.
MS25	First tests for producing HAh at gram scale	12 - Bio_Ch	28	Report available - this milestone will attest the completion of first tests for producing hyaluonic acid products at gram scale.
MS26	First trials for incorporating HAh into cosmetics	15 - EVO	30	Report available - this milestone will attest the completion and outcomes of the first cosmetic production tests.
MS27	First report on product characteristics	1 - CSIC	34	Report available - this milestone will attest the completion and outcomes of the properties and benefits of products obtained by integrating or using new enzymes.
MS28	First LCA report for the 3 FuturEnzyme products	8 - ITB	40	Report available - this milestone will attest the completion of the LCA for the production of the final 3 products produced at large.


2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
WP 1
T1.1 Technical, administrative and financial management (1-48)
T1.2 Confidentiality legal documents Inter-Consortia for establishing synergies (1-48)
WP 2
T2.1 Compile the on-demand manufacturers' needs and specifications (1-6)
T2.2 Pre-selecting candidate sequences through extensive homology search (1-48)
T2.3 Motif buildup for massive and smart search of enzymes fitting manufacturers' needs (1-42)
T2.4 Iterative and decision-making hierarchical procedure for speed up enzyme discovery (3-48)
WP 3
T3.1 Exploitation of the FuturEnzyme bio-resource collections (1-24)
T3.2 Sampling extreme environments for generating new microbial bio-resources (6-30)
T3.3 Next Generation Sequencing for generating sequences of target enzymes (1-36)
WP 4
T4.1 Ultra-fast and efficient gene cloning and synthesis: downstream enzyme production (2-30)
T4.2 Sampling extreme environments for generating new microbial bio-resources (2-30)
T4.3 Production of enzymes from their natural hosts (2-30)
T4.4 Enzyme characterisation for selecting those with manufacturers' specifications (2-36)
T4.5 Decision-making strategy for selecting lead enzyme candidates (6-36)
T4.6 Design of multi-enzyme blends to process complex ingredient mixtures (12-40)
WP 5
T5.1 Disruptive engineering computational tools (3-42)
T5.2 Developing disruptive PluriZymes with multipurpose activities (6-42)
T5.3 Other advanced and classical mutation methods (4-42)
T5.4 Empowering enzymes by immobilization-guided supramolecular engineering (6-40)
WP 6
T6.1 Fermentation and DSP of best 18 project enzymes (16-42)
T6.2 Upscaling (non-GMP) fermentation and DSP of 9 best enzymes (20-48)
T6.3 Development of optimised formulations of 9 lead enzyme candidates (20-48)
T6.4 Safety, risk and environmental impact assessments of enzyme supply (20-48)
WP 7
T7.1 Pre-industrial validations: formulation of real-life and solution-oriented detergents (20-48)
T7.2 Pre-industrial validations: formulation of real-life and solution-oriented textiles (20-48)
T7.3 Pre-industrial validations: formulation of real-life and solution-oriented cosmetics (20-48)
T7.4 LCA assessments: detergent, textile and cosmetic products (1-48)
WP 8
T8.1 Dissemination and Communication (1-48)
T8.2 FuturEnzyme Website and strong on-line meeting platform (1-48)
T8.3 Dissemination and Communication: toolkit and public relations (PR) (1-48)
T8.4 Education and Training (1-48)
T8.5 Maximising exploitation of project enzymes, products, and knowledge (1-48)
T8.6 Maximising data management – the internal FuturEnzyme repository (1-48)
T8.7 Maximising synergies with other consortia (1-48)
WP 9
T9.1 Ethic requirements (1-48)
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48

Tasks 7.1-7.3 Pre-industrial validations: formulation of real-life and solution-oriented detergents/textiles/cosmetics

- Starting in M20 (Jan 2023)
- Requirements:
  - (First) enzyme candidates identified
  - (First) enzyme activity proven at lab scale
  - (First) production and purification protocol established
  - (First) tech transfer to liter scale completed

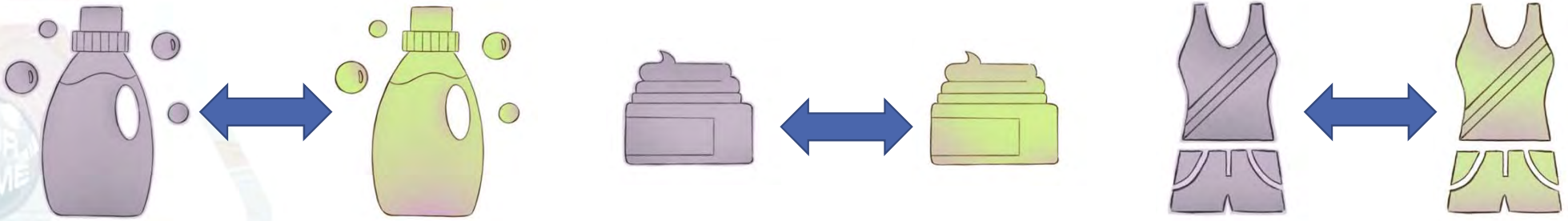
Task 7.4: Life Cycle Assesment

Objective of the task:

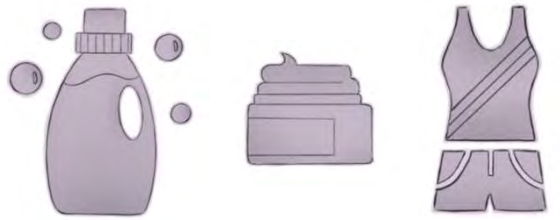
To demonstrate that innovative products with the selected enzymes have **better environmental profile** that their current alternative

- To perform LCA of the **three best performers** (one per each application: detergent, cosmetic, textile) and compare them with **three benchmarks**

- **6 LCA** studies to be run within the task (3 comparisons)



Benchmark Products



Steps of LCA studies

Goal and scope definition	We define what we want to analyse and how
Life cycle inventory analysis	We collect data on inputs and outputs of the system(s) analysed
Impact assessment	We calculate results of environmental impacts generated
Interpretation of results	Analysis of results (identification of hotspots, improvements, etc)

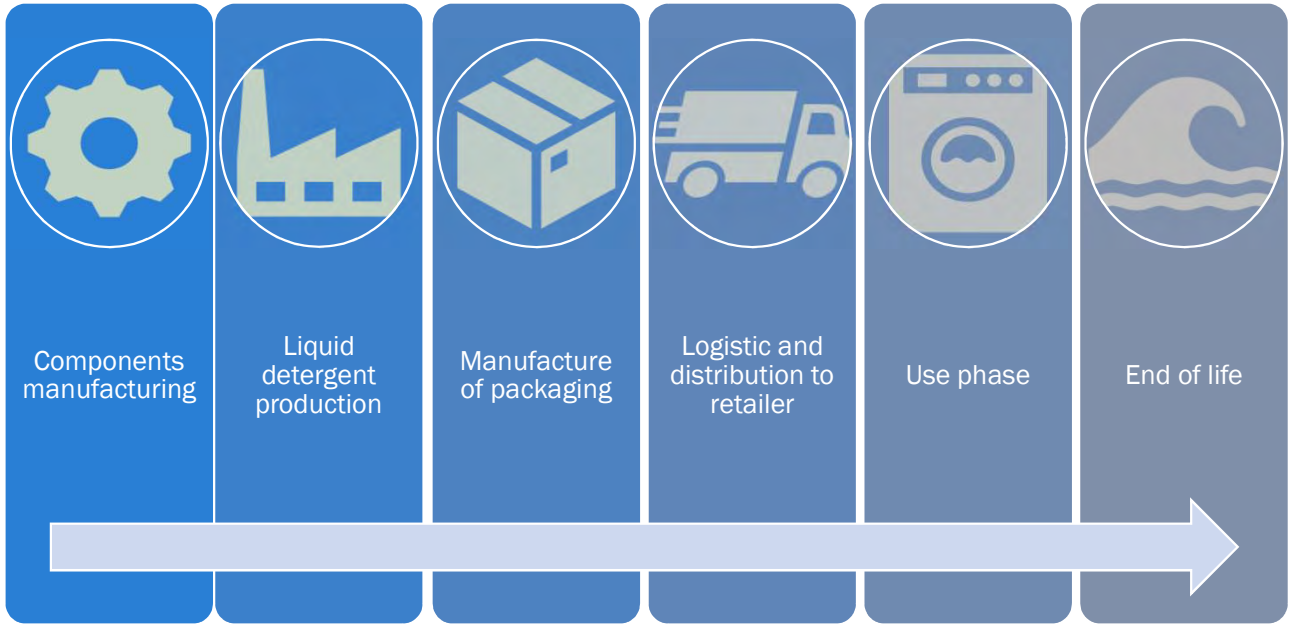
Benchmark Detergent

Goal and scope definition

- *Functional unit*: 650 mL laundry detergent liquid

- *Product description*:
  - Product density: 1.09 g/mL
  - Product lifespan: under a year
  - 1 laundry cycle: 65 mL (10 laundry cycles per bottle)

- *System boundaries*: cradle-to-grave



Benchmark Detergent

Life Cycle Inventory – components manufacturing

Representative average product and baseline use scenario modelled considering the statistics about household consumptions in EU.
Reference: *PEFCR pilots: Heavy Duty Liquid Laundry Detergents (HDLLD) for machine wash*

Ingredients group	Chemicals	Assumption on concentration (wt%)	Quantity (g)	Ecoinvent dataset for FuturEnzyme project
Water	Water	70,22%	497,5087	Water, deionised {Europe without Switzerland}| market for water, deionised | Cut-off, U
Builders	Citric acid	1,61%	11,40685	Citric acid {GLO}| market for | Cut-off, U
	Salts of citric acid	0,67%	4,74695	Citric acid {GLO}| market for | Cut-off, U
Sequestrants	Sodium phosphonate	0,41%	2,90485	Sodium phosphate {RER}| market for sodium phosphate | Cut-off, U
Enzymes		0,58%	4,1093	Enzymes {GLO}| market for enzymes | Cut-off, U
Dye		0,03%	0,21255	Cyanuric chloride {GLO}| market for | Cut-off, U
Fragrances		0,71%	5,03035	Dodecanol {GLO}| dodecanol production, from coconut oil | Cut-off, U
				3-methyl-1-butanol {GLO}| market for | Cut-off, U, at plan
				Benzaldehyde {RoW}| market for benzaldehyde | Cut-off, U
				Benzyl alcohol {GLO}| market for | Cut-off, U

Benchmark Detergent

Life Cycle Inventory – components manufacturing

Representative average product and baseline use scenario modelled considering the statistics about household consumptions in EU.
Reference: *PEFCR pilots: Heavy Duty Liquid Laundry Detergents (HDLLD) for machine wash*

Ingredients group	Chemicals	Assumption on concentration (wt%)	Quantity (g)	Ecoinvent dataset for FuturEnzyme project
Optical brighteners	Optical brighteners	0,03%	0,21255	Fluorescent whitening agent, distyrylbiphenyl type {GLO}| market for | Cut-off, U
	Optical brighteners	0,03%	0,21255	Fluorescent whitening agent, DAS1, triazinylaminostilben type {GLO}| market for | Cut-off, U
Surfactant system	Sodium alkyl ether sulfates	3,55%	25,15175	Fatty alcohol sulfate {GLO}| market for fatty alcohol sulfate | Cut-off, U
	alkylbenzene sulfonate (LAS)	6,83%	48,39055	Alkylbenzene sulfonate, linear, petrochemical {GLO}| market for | Cut-off, U
	Soap	2,41%	17,07485	Fatty acid {GLO}| market for | Cut-off, U
	Ethoxylates oleochemicals + petrochemical & other non-ionic surfactant	5,91%	41,87235	Non-ionic surfactant {GLO}| market for non-ionic surfactant | Cut-off, U
Alkalinity sources	Sodium hydroxide	1,72%	12,1862	Sodium hydroxide, without water, in 50% solution state {GLO}| market for | Cut-off, U
	Triethanolamine	0,59%	4,18015	Triethanolamine {GLO}| market for | Cut-off, U

Benchmark Detergent

Life Cycle Inventory – components manufacturing

Ingredients group	Chemicals	Assumption on concentration (wt%)	Quantity (g)	Ecoinvent dataset for FuturEnzyme project
Solvents	Glycerine	0,58%	4,1093	Glycerine {GLO}| market for | Cut-off, U
	Propylene glycol	2,27%	16,08295	Propylene glycol, liquid {GLO}| market for | Cut-off, U
	Other solvents			Solvent, organic {GLO}| market for | Cut-off, U
Other ingredients	Preservatives	0,02%	0,1417	Benzo[thia]diazole-compound {GLO}| market for | Cut-off, U
	Polymers	0,70%	4,9595	Polycarboxylates, 40% active substance {RER}| market for polycarboxylates, 40% active substance | Cut-off, U
	Sodium chloride	0,42%	2,9757	Sodium chloride, powder {GLO}| market for | Cut-off, U
	Others	0,70%	4,9595	Chemical, organic {GLO}| market for | Cut-off, U

ITB will share this inventory with Henkel to collect input on how to implement it (especially on the surfactant composition which is a crucial element for the innovative product)

Benchmark Detergent

Life Cycle Inventory – Detergent production

Missing information on:

- Water consumption
- Energy consumption
- Waste production
- Direct emission

*Data should be expressed per product unit where product unit = one bottle of detergent of 650 mL

Life Cycle Inventory – Packaging manufacturing

Packaging	Material	Quantity per unit of product (g)
Primary	Bottle in HDPE	3,7
	Cap in PP	0,8
	Paper labels	0,1
	Recycled plastic content	0%
Secondary	Cardboard box	15

Benchmark Detergent

Life Cycle Inventory – Use phase

- Washing temperature: 40°C
- Amount per cycle: 65 mL

Use phase consumption	Quantity	Unit	Ecoinvent database
Water consumption	50	L	Tap water technology mix at user per kg of water
Energy consumption	0,6378*	kWh	Electricity grid mix 1kV-60kV AC, technology mix consumption mix, at consumer 1kV-60kVVEU-28+3

*This is calculated accordingly to the formula in the publication: *PEFCR pilots: Heavy Duty Liquid Laundry Detergents (HDLLD) for machine wash*

Life Cycle Inventory – End of life

Calculation will be made based on the specific composition of the disposed wastewater which, in turns, depends on the final composition of the detergent

Benchmark Detergent

???

Requests for Henkel

1. **Revise the benchmark composition** ITB defined on a literature basis. We need to know if this corresponds to Henkel's benchmark. Any modifications or suggestions on this composition are welcomed, especially on the surfactant composition which is a crucial element for the LCA.

2. Provide some suggestions on the **consumptions of the production process** of an average detergent.

3. For the innovative detergent, does Henkel foresee to reduce the use of detergent per cycle with respect to a standard detergent? Which **quantity** does Henkel foresee **to use per each cycle**?

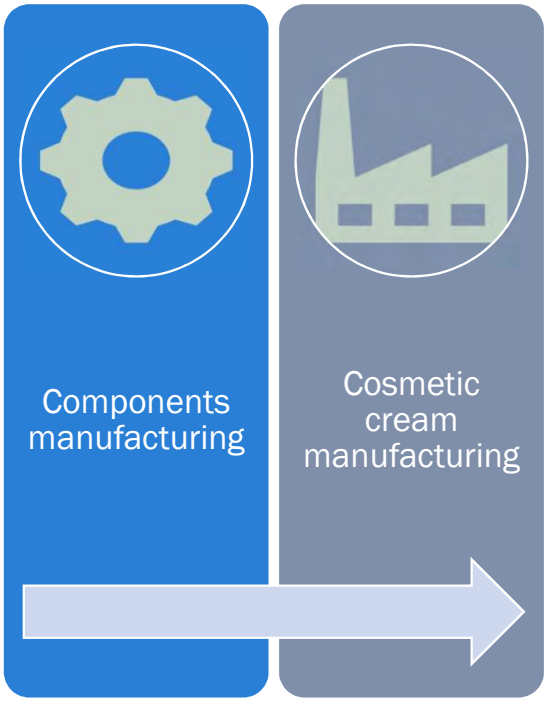
Benchmark Cosmetic

Goal and scope definition

- *Functional unit*: 1 kg of face cream with fragmented hyaluronic acid

- *Product description*:
  - Product lifespan: under a year
  - Hyaluronan produced via the standard chemical route

- *System boundaries*: cradle-to-gate



Benchmark Cosmetic

Life Cycle Inventory – components manufacturing

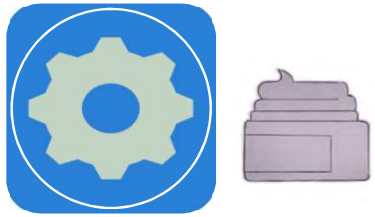
Composition of a face cream produced by Unifarma SpA (data from EPD documents, 2016)

ITB included the whole formulation of the cream because we do not know if something will change with the introduction of the innovative ingredient. ITB will revise it later based on the data that will be received in the next phases of the project.

Ingredients group	Chemicals	Assumption on concentration (wt%)	Quantity (g)	Ecoinvent dataset for Futurenzyme project
Water	Water	87,84%	878,35	Water, deionised {Europe without Switzerland}| market for water, deionised | Cut-off, U
Humectant	Glycerine	4,98%	49,75	Glycerine {GLO}| market for | Cut-off, U
Lipids	Dimethicone	2,00%	20	TBD
	Dimethicone crosspolymer	1,50%	15	TBD
	Cyclopentasiloxane	0,50%	5	TBD

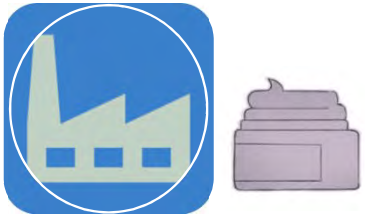
Benchmark Cosmetic

Life Cycle Inventory – components manufacturing



Ingredients group	Chemicals	Assumption on concentration (wt%)	Quantity (g)	Ecoinvent dataset for Futurenzyme project
Rheology modifier	Sodium acrylate/sodium acryloyldimethyl copolymer	0,58%	5,8	
	Isohexadecane	0,25%	2,5	
	Polysorbate 80	0,10%	1	
	Ammonium acrylolydimethyltaurate/VP copolymer	0,50%	5	
	Dehydroxanthan gum	0,20%	2	
Antioxidant	Tocopheryl Acetate	0,50%	5	Cyanuric chloride {GLO}| market for | Cut-off, U
Parfum	Parfum	0,07%	0,7	Dodecanol {GLO}| dodecanol production, from coconut oil | Cut-off, U 3-methyl-1-butanol {GLO}| market for | Cut-off, U, at plan Benzaldehyde {RoW}| market for benzaldehyde | Cut-off, U Benzyl alcohol {GLO}| market for | Cut-off, U
Preservatives	Caprylyl glycol	0,50%	5	
	Caprylyl glicine	0,15%	1,5	
Active principle	Sodium hyaluronate	3,55%	35,5	
Alkalinity sources	Sodium hydroxyde	1,72%	17,2	Sodium hydroxide, without water, in 50% solution state {GLO}| market for | Cut-off, U

Benchmark Cosmetic



Life Cycle Inventory – hyaluronic acid fragments production

Missing information!

ITB is studying patents to identify relevant processes and collect as many data as possible.

→ If Evonik has some patents on this topic (production of hyaluronic acid via the chemical route) or some data on the consumptions (energy, water, direct emissions and waste production), please provide them to ITB!

Life Cycle Inventory – cosmetic production

Missing information on:

- Water consumption
- Energy consumption
- Waste production
- Direct emission

Benchmark Cosmetic

???

Requests for Evonik

1. **Revise the benchmark composition** ITB defined on a literature basis. We need to know if this corresponds to Evonik's benchmark. Any modifications or suggestions on this composition are welcomed, especially on the surfactant composition which is a crucial element for the LCA.

2. Provide some suggestions on the **consumptions of the production process** of an average cosmetic.

3. Have you conducted **previously LCA** studies that ITB can review? And/or have you collected some patents or other LCAs on hyaluronic acid fragmentation with standard procedures?

Benchmark Textile

Goal and scope definition

- *Functional unit*: 1 kg of textile (what type of textile?)

- *System boundaries*: To be defined (it depends on the type of innovation)

Benchmark Textile

???

Requests for Schoeller

1. On which **innovation**(s) and **type of textile** should we **focus for the LCA?** ITB reads about several hypothesys but they can't focus on every of them?
   → Which innovation on which type of textile is most important for you / is expected to have the highest impact on your treatment?

2. Have you conducted **previously LCA studies** that ITB can review? And/or have you collected some patents or other LCAs on textile production with standard procedures?

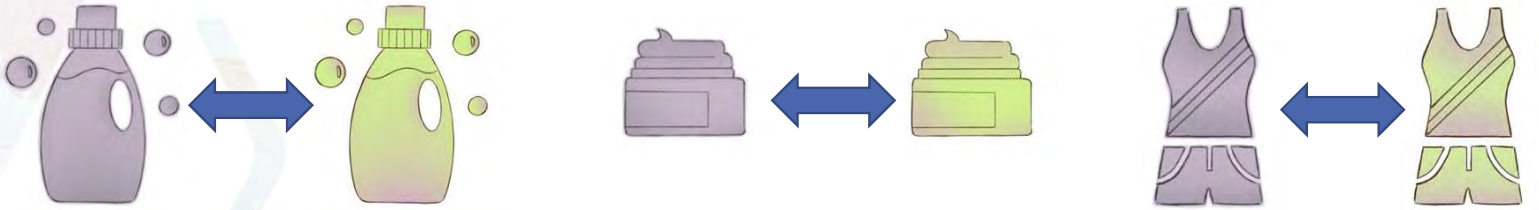
Task 7.4: Life Cycle Assesment

Next steps:

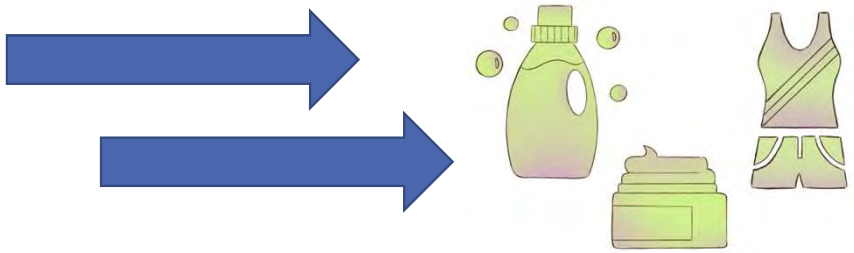
CLIB will initiate product-specific short online meetings with ITB and each manufacturer to:

- clarify the presented open questions on the benchmark processes / products
- discuss which data is required / important for a reliable LCA of the greener products and how this data could be obtained

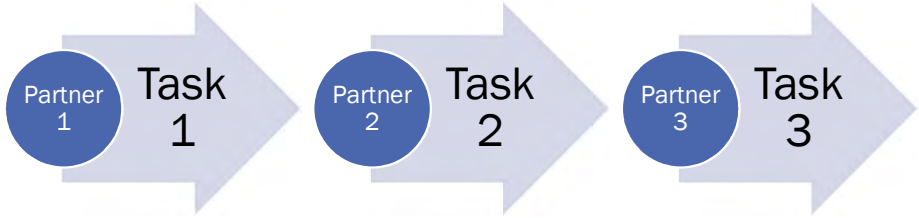
→ Meetings will be scheduled in the end of July / beginning of August



Tasks 7.1-7.3: Next steps



- Regular „Formulation Meetings“, minimum every 6 months
  - Organised by CLIB
  - Starting in summer 2022
  - Streamlined feedback from manufacturers to enzyme producers and developers
  - Targeted development and scale-up of production processes
    → communicate requirements for final formulation
  - Maintain iteration loop with WP6 (including Eucodis / Inofea?)
  - Definition of decision criteria which enzymes to work on with
- Definition of key requirements / goals to be achieved in previous WPs to start formulation tests / small-scale trials
- Contact CLIB for any questions / requests



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