FuturEnzyme
Technologies of the FUTURe for low-cost ENZYMEs for environment-friendly products

Executive meeting #2

14th November 2022 / Markus Müller, CLIB, mueller@clib-cluster.de

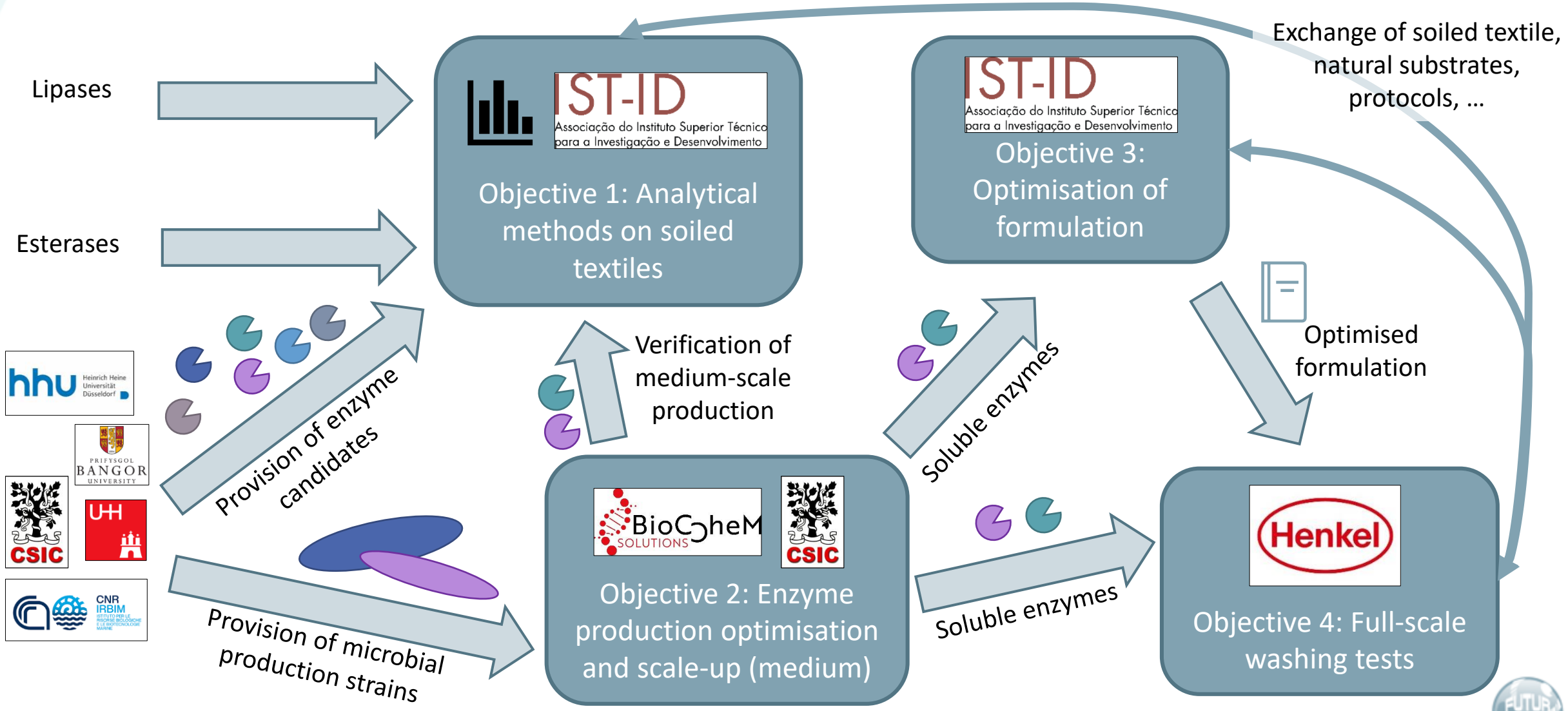
WP7: Formulation and manufacturing of consumer products: sustainability and environmental assessments

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

Activities and discussions in WP7

- WP7.1: Pre-industrial validations: formulation of real-life and solution-oriented **detergents**
- WP7.2: Pre-industrial validations: formulation of real-life and solution-oriented **textiles**
- WP7.3: Pre-industrial validations: formulation of real-life and solution-oriented **cosmetics**
- WP7.4: **LCA assessments**: detergent, textile and cosmetic products

Task 7.1: Pre-industrial validation: Detergents

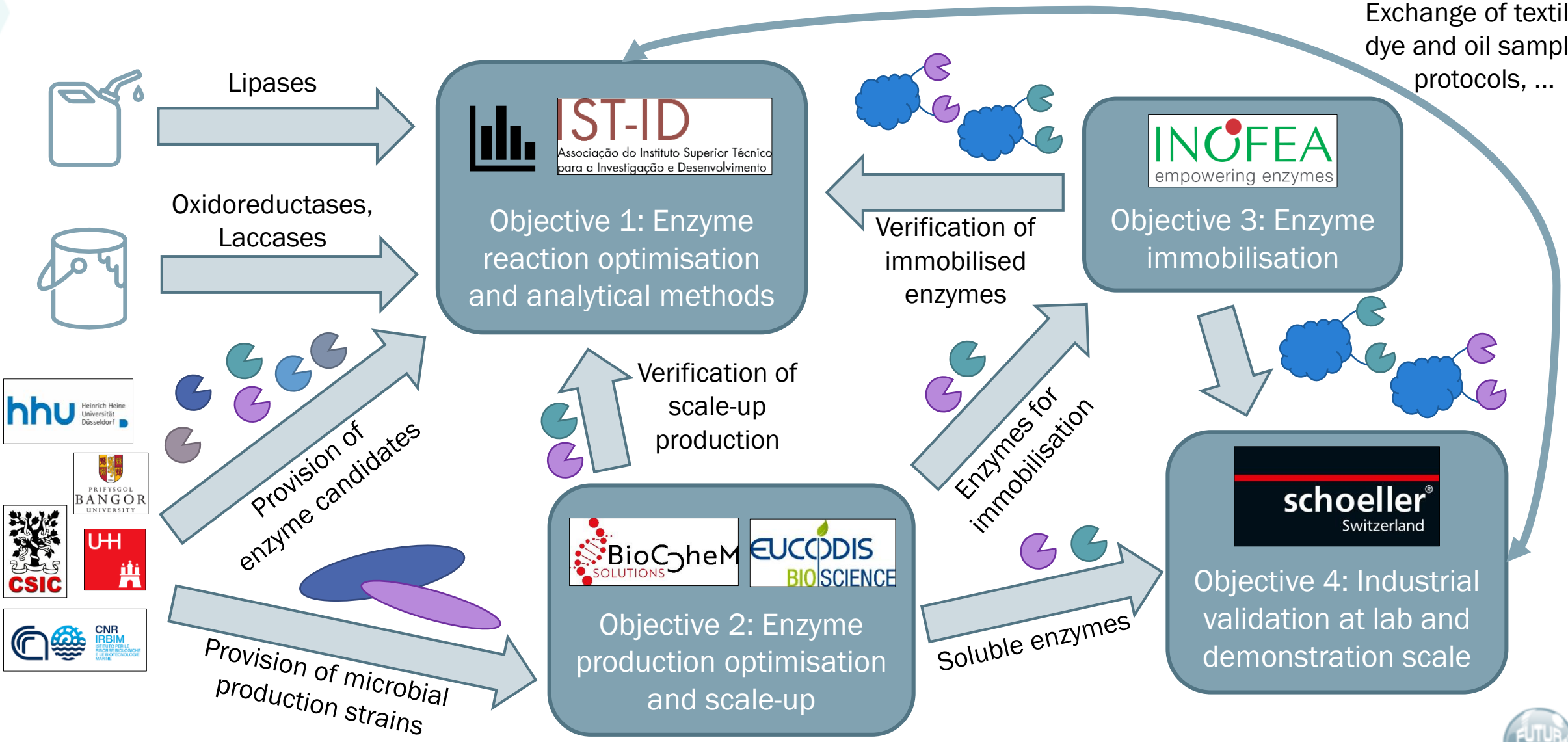


Task 7.1: Pre-industrial validation: Detergents

Key decisions and information for further development

- Main target enzymes: Lipases, esterases
- Henkel will be involved early-on in small-scale washing trials on real stains (limited number of enzyme candidates)
- Enzyme characterization in washing liquor (not in buffer)
- Required amount of enzyme for full-scale washing trials: 0.2 - 1 g per enzyme (depending on activity) → production by **BIO_CH** / **CSIC**
- Henkel will share with academic partners **fabric soils** with specific compounds and **list of** consumer-relevant **complex substrates**

Task 7.2: Pre-industrial validation: Textiles

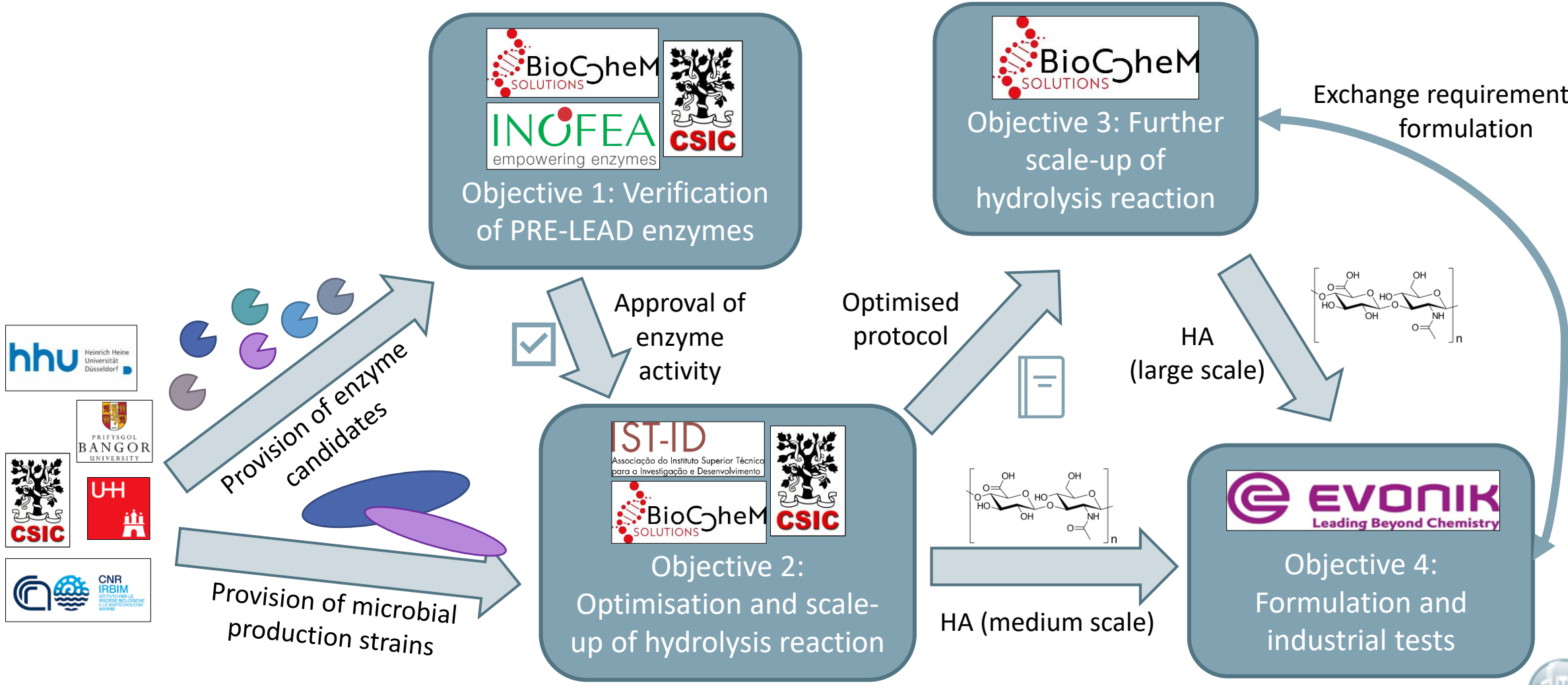


Task 7.2: Pre-industrial validation: Textiles

Key decisions and information for further development

- Focus applications: Cleaning of yarn from oils (lipases), remove excess dye (oxidoreductases, laccases)
- Maximal time of enzyme treatment: 24 h (shorter preferable)
- Maximal target size of textile to be treated (within project): 1 m^2
- Optimal reaction conditions to be determined by academic partners
- Required amount of enzyme for Schoeller trials: Depending strongly on activity → production planned by **BIO_CH / EUC** (will be determined at later stage)
- Schoeller will share with academic partners **fabrics, yarn and dye** for enzyme screening and reaction optimisation

Task 7.3: Pre-industrial validation: Cosmetics



Task 7.3: Pre-industrial validation: Cosmetics

Key decisions and information for further development

- Target for Evonik: Enzymatically hydrolysed HA to be used in cosmetic products (not the enzyme itself)
- Focus on soluble enzymes; reaction conditions at low energy and environmental footprint level
- Ensure removal of enzyme (40-80 kDa) from treated HA, potentially by ultra filtration @Evonik
- Required amount of HA for Evonik trials: 10 - 100 g → enzyme production production planned by **CSIC / BIO_CH / EUC** (will be determined at later stage, depending on kinetics of hydrolysis reaction)
- Evonik will define in collaboration with academic partners **standard conditions** for the enzyme reaction and **product requirements**

Task 7.1-7.3: Roadmap

			Jan 23	Feb 23	Mrz 23	Apr 23	Mai 23	Jun 23	Jul 23	Aug 23	Sep 23	Okt 23	Nov 23	Dez 23	Jan 24	Feb 24	Mrz 24	Apr 24	Mai 24	Jun 24	Jul 24	Aug 24	Sep 24	Okt 24	Nov 24	Dez 24	Jan 25	Feb 25	Mrz 25	Apr 25	Mai 25
Task	**Objective (short)**	**(Main) Partners**	**M20**	**M21**	**M22**	**M23**	**M24**	**M25**	**M26**	**M27**	**M28**	**M29**	**M30**	**M31**	**M32**	**M33**	**M34**	**M35**	**M36**	**M37**	**M38**	**M39**	**M40**	**M41**	**M42**	**M43**	**M44**	**M45**	**M46**	**M47**	**M48**
7.1: Detergents	O1: Analytical methods on soiled textiles	IST-ID, Henkel																													
	O2: Enzyme production optimisation and scale-up	Bio_CH, CSIC, UDUS, IST-ID																													
	O3: Optimisation of formulation	IST-ID, Henkel, UDUS, Bangor, CSIC																													
	O4: Full-scale washing tests	Henkel																													
7.2: Textiles	O1: Enzyme reaction optimisation and analytical	IST-ID, Schoeller, (INOFEA)																													
	O2: Enzyme production optimisation and scale-up	Bio_CH, EUC, IST-ID																													
	O3: Enzyme immobilisation	INOFEA, IST-ID																													
	O4: Industrial validation at lab and demonstration scale	Schoeller																													
7.3: Cosmetics	O1: Verification of PRE-LEAD enzymes	CSIC, Bio_CH, INOFEA, IST-ID, CNR																													
	O2: Optimisation and scale-up of hydrolysis reaction	IST-ID, CSIC, Bio_CH																													
	O3: Further scale-up of hydrolysis reaction	CSIC, Bio_CH																													
	O4: Formulation and industrial tests	Evonik																													

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

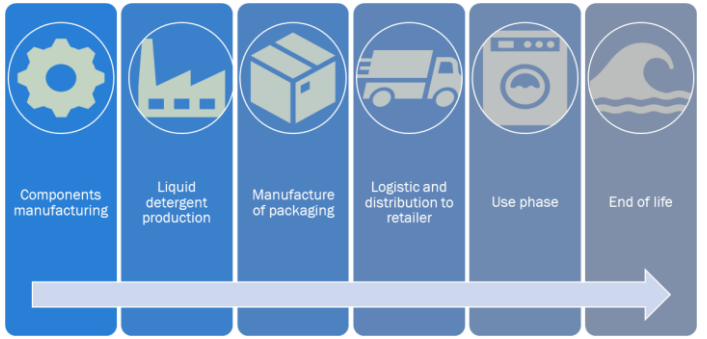
- To perform LCA of the three best performers (one per each application: detergent, cosmetic, textile) and compare them with three benchmarks

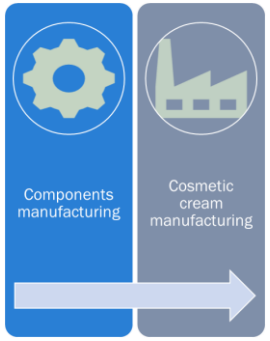
- 6 LCA studies to be run within the task (3 comparisons)

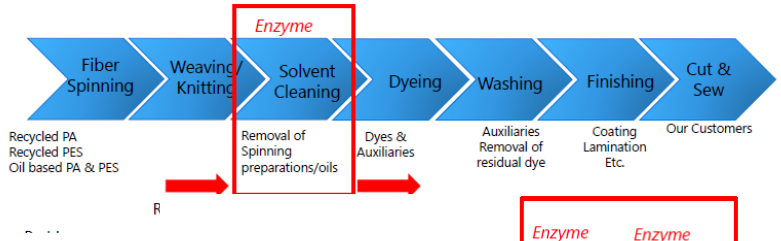
Task 7.4: Life Cycle Assesment

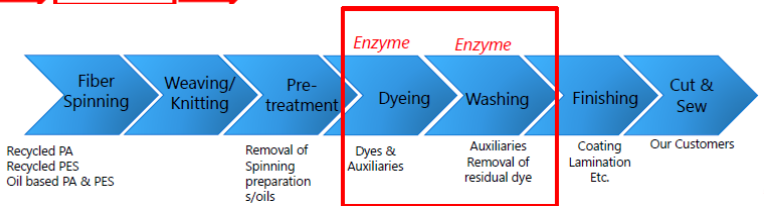
Status update:

- Individual LCA meetings with industry partners conducted
  - ➢ Definition of benchmark processes / products
  - ➢ Update of data basis after input from industry partners
  - ➢ Clarification of system boundaries
- Further information requested
  - ➢ Filling of data gaps for benchmark processes









Outlook and open discussion

- Current status of **enzyme selection** by academic partners
  → Importance of high-quality enzyme database (shown by Manolo)!
- Next steps towards **scale-up of enzyme production (WP6)**
  → Design freeze at end of May 2023?
- **Schedule** for medium to large scale enzyme preparations and subsequent tests/verifications

- Next industry meetings planned for **January 2023** (with academic partners)

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Task 7.4: LCA – benchmark products

Steps of LCA studies

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

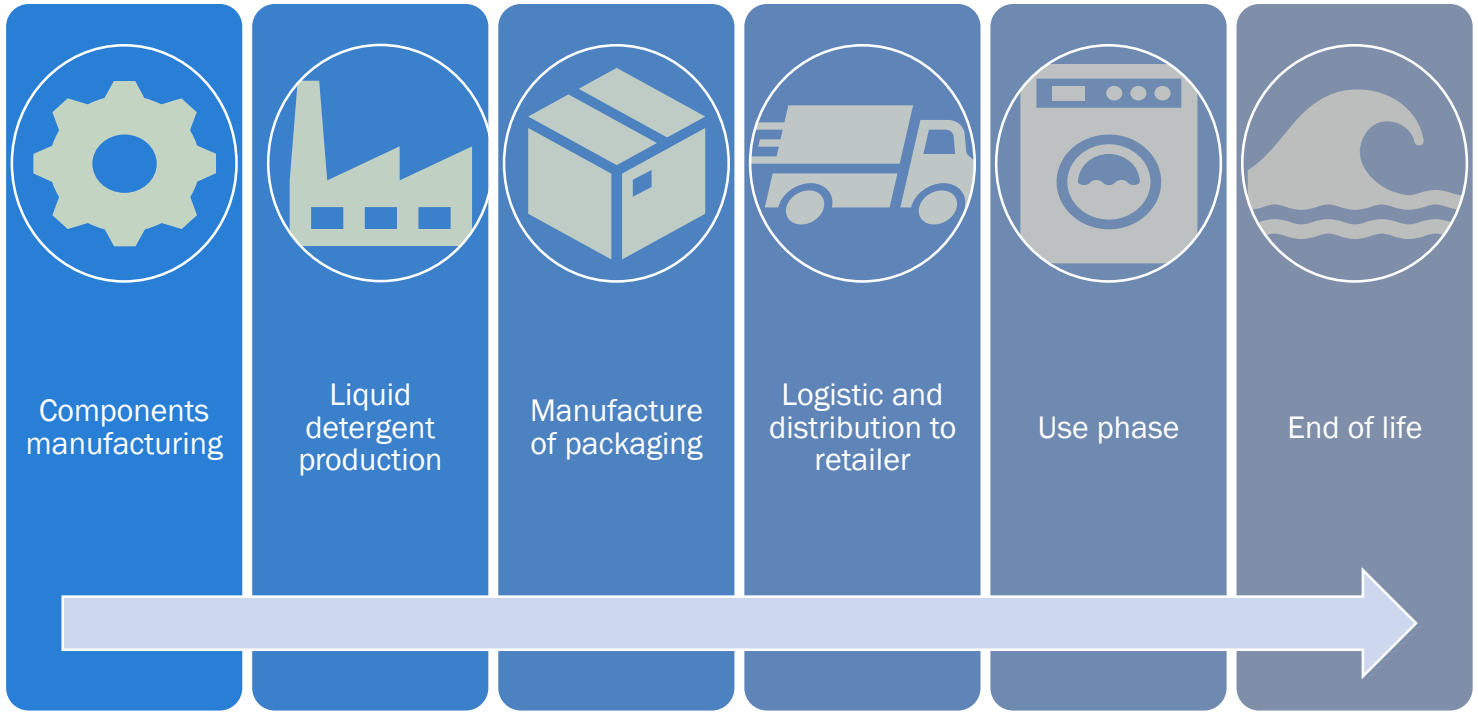
Task 7.4: LCA – benchmark detergent

Goal and scope definition

Data updated after meeting with Henkel

➢ *Functional unit:* 1 L (1,054 kg) laundry detergent liquid

➢ *System boundaries*: cradle-to-grave



➢ *Product description*:

- Product density: 1.054 g/mL
- Product lifespan: under a year
- 1 laundry cycle: 53 g (20 laundry cycles per bottle)

Task 7.4: LCA – 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

Task 7.4: LCA – benchmark detergent

Life Cycle Inventory – components manufacturing

Optical brighteneres	Optical brighteneres	0,03%	0,21255	Fluorescent whitening agent, distyrylbiphenyl type {GLO}| market for | Cut-off, U
	Optical brighteneres	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 hydroxyde	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

Task 7.4: LCA – benchmark detergent

Life Cycle Inventory – components manufacturing

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

Already discussed and approved by Henkel

Task 7.4: LCA – benchmark detergent

Life Cycle Inventory – detergent production

Missing information on:

- Water consumption: 0.6 L/kg
- Energy consumption: 0.16 kWh/kg
- **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	2,11
	Cap in PP	0,46
	Paper labels	0,06
	Recycled plastic content	0%
Secondary	Cardboard box	15

Based on a 1,054 kg bottle

Task 7.4: LCA – benchmark detergent

Life Cycle Inventory – Use phase

- Washing temperature: 40 °C
- Amount per cycle: 53 g

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

Task 7.4: LCA – benchmark cosmetic

Goal and scope definition

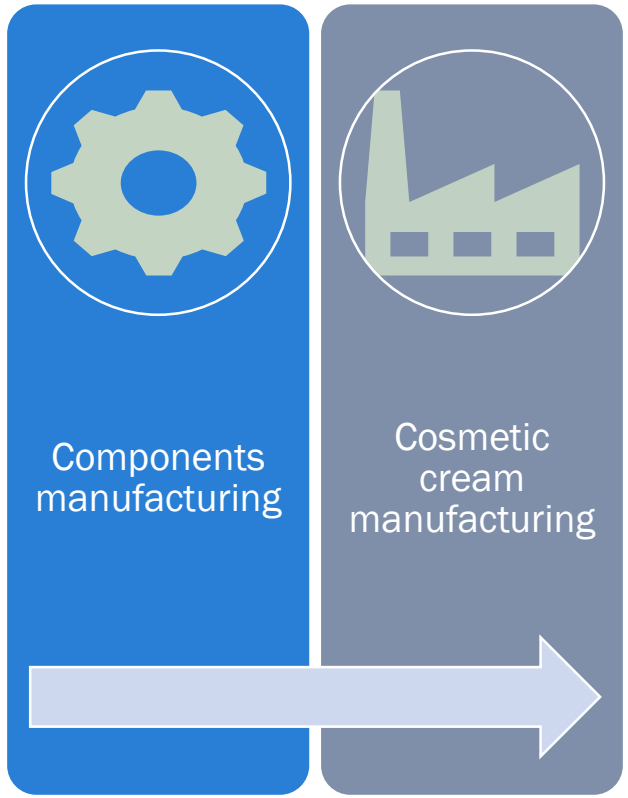
Data updated after meeting with Evonik

➢ *Functional unit*: 1kg of face cream with fragmented hyaluronic acid (5kDa)

➢ *Product description*:

- Product lifespan: under a year
- Hyaluronan produced via thermical process vs enzymatic route

➢ *System boundaries*: cradle-to-gate



Task 7.4: LCA – benchmark cosmetic

Life Cycle Inventory – components manufacturing

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

We included the whole formulation of the cream because we do not know if something will change with the introduction of the innovative ingredient. We will revise it later based on the data we will receive 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

Task 7.4: LCA – benchmark cosmetic

Life Cycle Inventory – components manufacturing

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

Task 7.4: LCA – benchmark cosmetic

Life Cycle Inventory – hyaluronic acid fragments production

Missing information!

We are studying patents to identify relevant processes and collect as many data as possible.

Can you provide a **workflow** of the macro-steps of the production process both using the benchmark and the innovative technologies?

Life Cycle Inventory – cosmetic production

Missing information on:

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

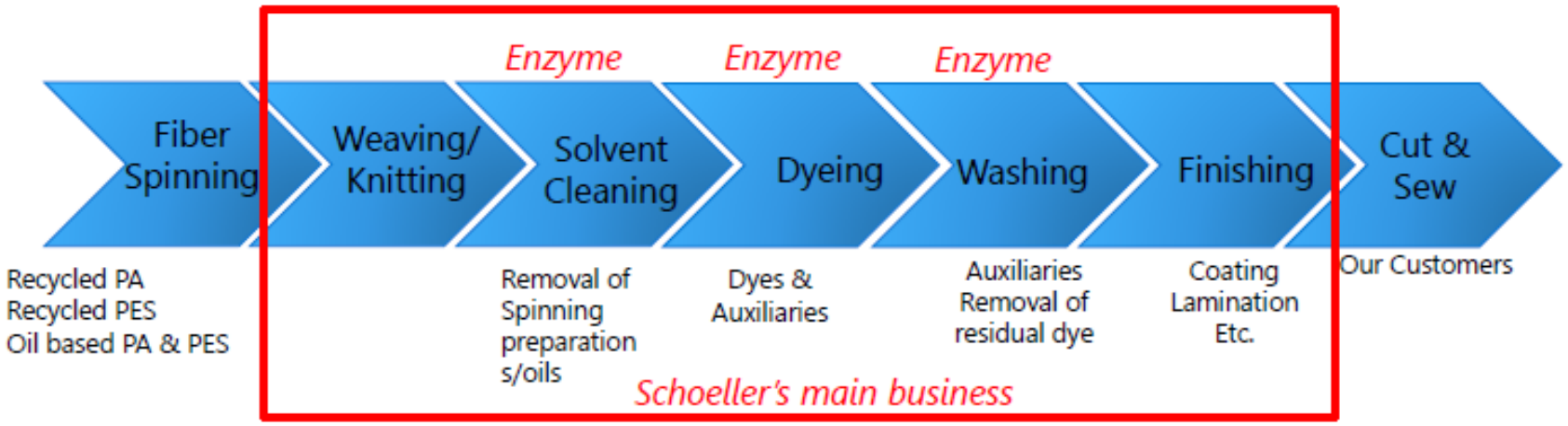
Task 7.4: LCA – benchmark textile

Goal and scope definition

Data updated after meeting with Schoeller

- *Functional unit*: 1kg of textile (focusing on PES as it is the most used at global level)

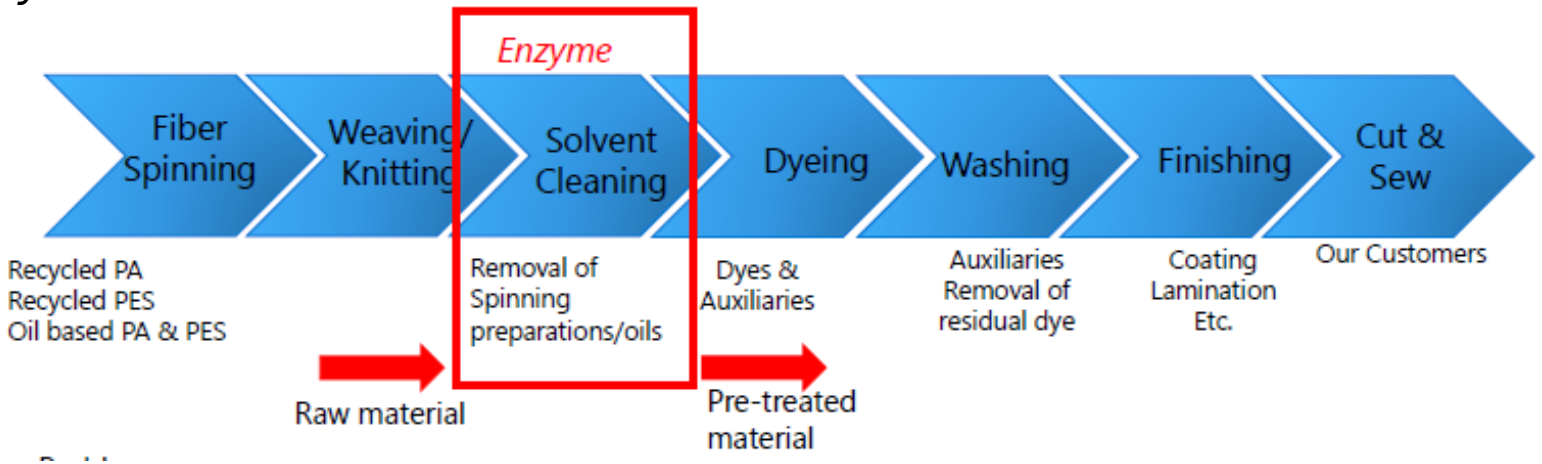
- *System boundaries*: cradle-to-gate (easier access to information)



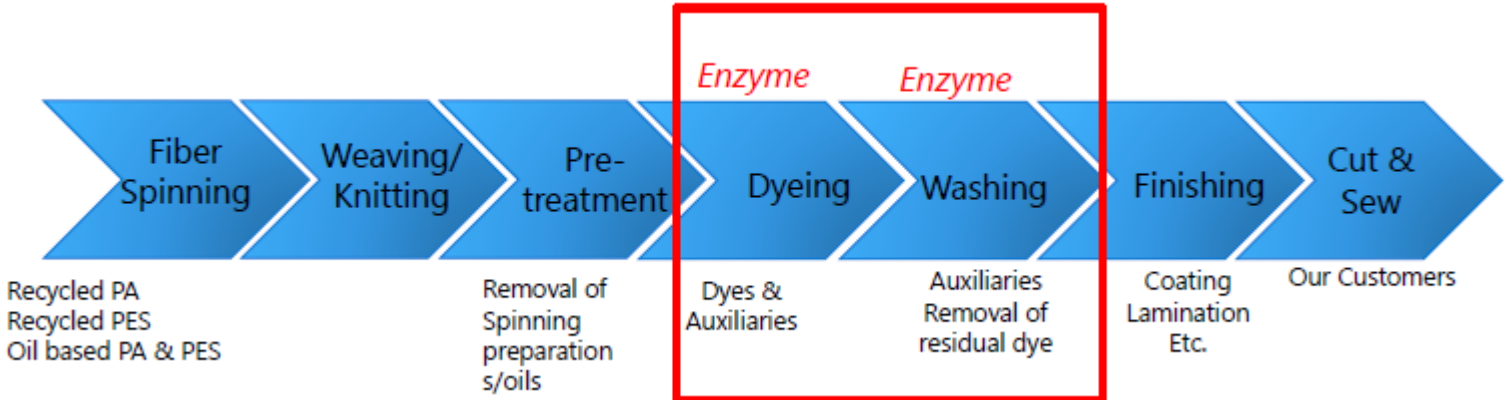
Task 7.4: LCA – benchmark textile

Innovation focus

Cleaning the synthetic material



Improve the sustainability of the dyeing process



Task 7.4: LCA – benchmark textile

Life Cycle Inventory

Already received some data on specific steps of the production process (e.g. dyeing).

We will provide to Schoeller an excel file to be completed with the consumption values for each step of the production process (for the benchmark product).