Eco-Efficient Dry Wool Scouring with total by-products recovery (LIFE11 ENV/ES/588)

Barcelona, 4th February 2016

With the contribution of the LIFE financial instrument of the European Union

WDS Welcome and Introduction

(LEITAT)

Initial WDS Consortium

- Coordinator:
  - AIICA-Asociación de Investigación de las Industrias del Curtido y Anexas

- Associated Beneficiaries:
  - Recuperación de Materiales Textiles S.A. (RMT SA)
  - Peinaje del Río Llobregat S.A. (PRLL SA)
  - Consejo Superior de Investigaciones Científicas – Instituto de Química Avanzada de Catalunya (CSIC-IQAC)

01/09/2012 - 31/08/2015

LEITAT managing your technologies | Technological Center member of TECNIO | RMT RECUPERACION DE MATERIALES TEXTILES S.A. | TAVARES Têxtil Manuel Rodrigues Tavares, SA | iQAC | CSIC

Partners changes

AIICA → LEITAT

Peinaje del Rio Llobregat, SA → Tavares (from 1/10/2013)

Project modification

- Technical complexity: Implementation actions modified to reach the objectives planned.

FINAL WDS Consortium

- Coordinator:
  - **LEITAT** Technological Centre

- Associated Beneficiaries:
  - Recuperación de Materiales Textiles S.A. (RMT SA)
  - Textil Manuel Rodrigues Tavares SA (TAVARES SA)
  - Consejo Superior de Investigaciones Científicas – Instituto de Química Avanzada de Catalunya (CSIC-IQAC)

→ 01/09/2012 - 28/02/2016

Expected impact

- A positive **impact on the employment,** through increasing the quality of wool and lanolin production while saving money on waste water treatment as well as water and energy consumption.
- **Wool sector** related actors could **gain competitiveness** such as wool trading companies.
- European **engineering and machinery companies.**
- The **improvement of the quality of wool**.

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RMT RECUPERACION DE MATERIALES TEXTILES S.A.
TAVARES Têxtil Manuel Rodrigues Tavares, SA
IQAC CSIC

WDS approach

(LEITAT)

Content

- Wool water scouring (problem)
- Breakthrough idea (solution) : Wool Dry Scouring (WDS)
- Solvent scouring
  Historical approaches
  Current situation (Taiwan)
- WDS concept approach
  WDS process layout
  WDS objectives

Wool water scouring

The greasy wool contains:

Wool fibre	40-80%
Suint	3 -12%
Wool wax (or wool grease)	6-20%
Dirt (or mineral matter)	5-20%
Vegetable matter	5-15%

Wool water scouring

Problems of wool scouring process:

Composition of Wool Scour Effluent*

Component	Amount (mg/L)
Wool Wax	3000-6000
Suint	3000-6000
Soil	4000-7000
Pesticide	<1
Biochemical Oxygen Demand (BOD)	2500-5000
Chemical Oxygen Demand (COD)	15000-30000
Suspended Solids (SS)	5000-10000
Total Nitrogen	200-500
Potassium	1000-1500
Ammonia N	40-120
Phosphorus	20-50
Total Surfactants	300-600
Sulphide	<1
Sulphate	30-100
Electrical Conductivity (EC)	1250-4000 µsiemens cm^{-1}
pH	7.5

*Data from Bateup, B O, Christoe, J R, and Russell, I M, CSIRO Division of Wool Technology, 1995. Refers to primary treated effluent. Assumptions: Australian wool, water consumption 10 L/kg greasy wool, primary recovery of 32% of the wax and 42% of the dirt.

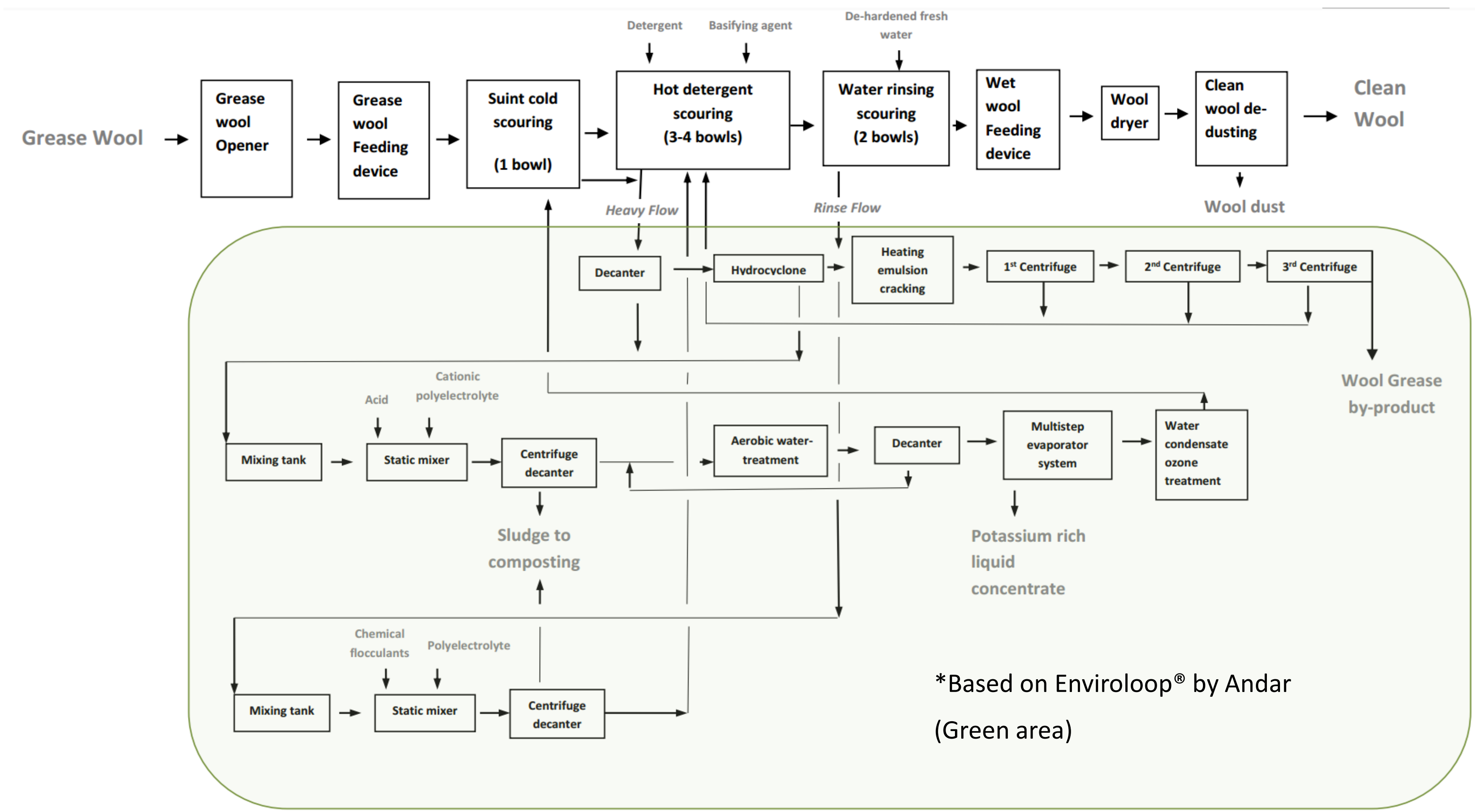
large quantities of wastewater
highly pollutant wool scour effluents

⇩ Wastewater treatments

expensive
(high capital and operating costs)

non-efficient
(treated effluents are still a problem, sludge containing grease and dirt)

Wool water scouring - Wastewater Treatment plant



*Based on Enviroloop® by Andar (Green area)

Wool water scouring

In Europe there are very few raw wool scourers left. The European wool scourers closed progressively because they could not afford the waste water treatments costs required to accomplish with the discharge limits to rivers or public sewers.

Wool is exported in raw state to China and India to be scoured, where the environmental legislation is less restrictive.

Breakthrough idea

Greasy wool solvent degreased and overdried liberates easily the non-fiber material as a fine dust

Breakthrough idea

Taking advantage of this fact we can achieve two goals :

- Full recovery of wool grease (Lanoline)

- Recovery of suint, dirt and vegetable matter directly as a solid material (dust)

Potential issues:

Working with solvent is not easy !!

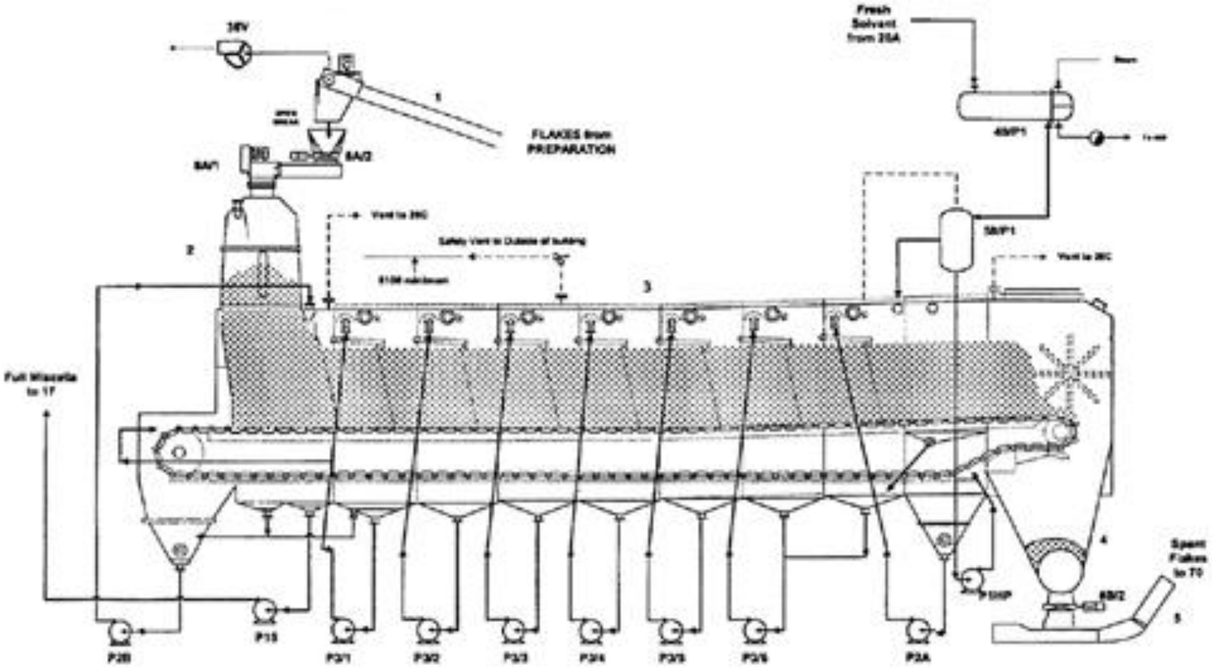
Historical approaches of solvent scouring

- During 1950s-1970s → commercial prototypes:
  - Prototype from Swedish Institute for Textile Research (hydrocarbon solvent)
  - CSIRO solvent jet process (hydrocarbon solvent)
  - Prototype from Yorkshire at the West Riding Woollen and Worsted Mills Ltd (tetrachloroethylene)
  - → prototypes did not have commercial success
- De **Smet process**, with seven plants in commercial operation in 1990 uses a combination of non-polar (hexane) and polar (isopropyl alcohol) solvents
  → there has been little further market success since 1990s
- Toa-Asahi, Japan (1983). Solvent: 1,1,1 trichloroethane.
  The wool was solvent degreased, dedusted and then given a conventional water scouring.
- Wooltech Ltd, Australia. Solvent: 1,1,2 trichloroethylene.

Solvent scouring - Historical approaches of solvent scouring

Common approach of previous solvent scouring processes:

- Replicate water process using solvent (use of bowls, rolling press, convective drying…)



Solvent scouring - Historical approaches of solvent scouring

Common issues of past previous processes using solvent:

- Loss of whiteness and softness
- Non-soluble solids become a mud made of dirt and solvent.
  - Drop in lanoline yield; solvent content difficult to recover; generation of a new waste
- Solvent recovery Wool Imbibed is challenging

- Fire and explosion risk
  - Flammable solvents: it is required to avoid explosives atmospheres.
  - This was avoided by using chlorate solvents but then:
    - Health and Environment hazardous (ozone-depleting substance)
    - Lanoline had little value as was contaminated

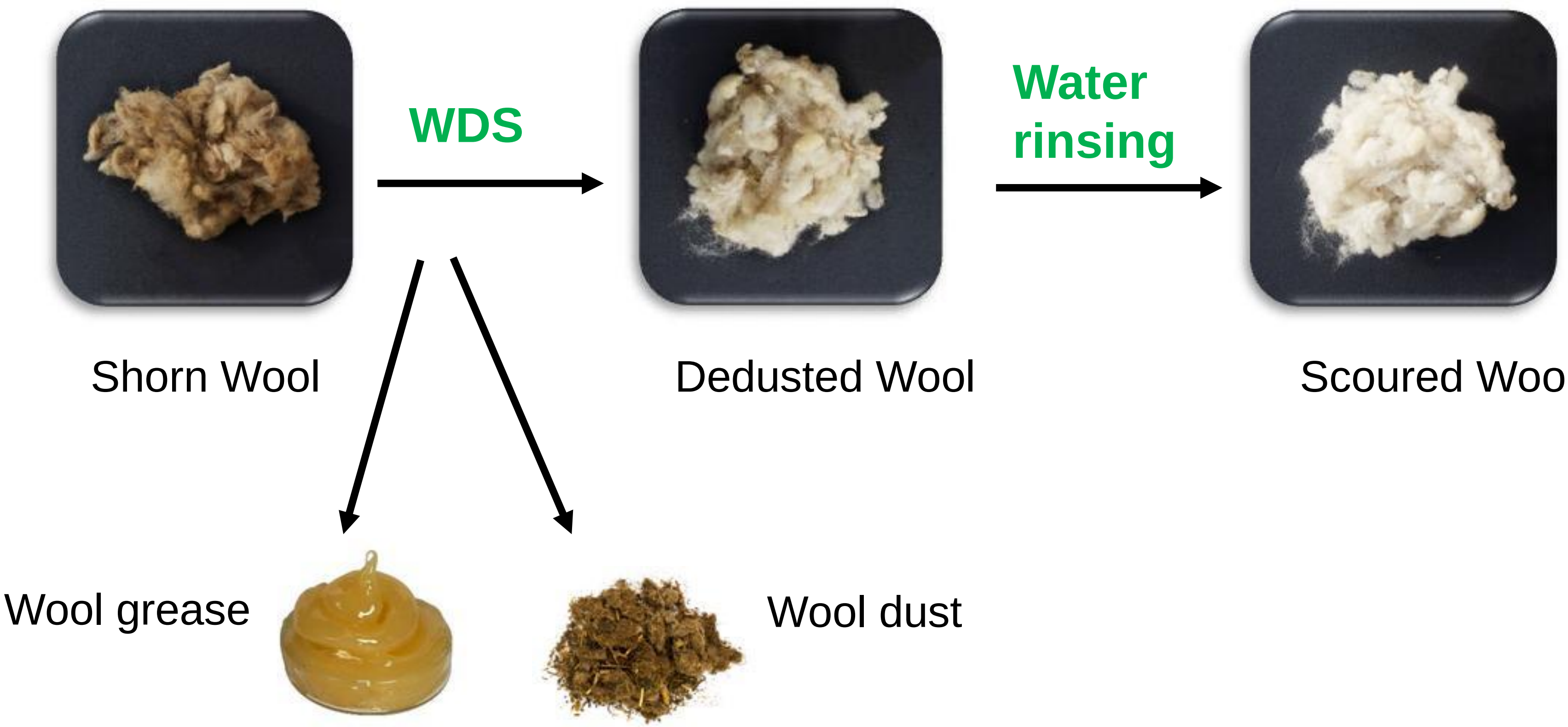
Solvent scouring - Current situation

Reward Wool Industry Corp. (Taiwan): the only company in the world using solvent to degrease wool and recover lanolin.

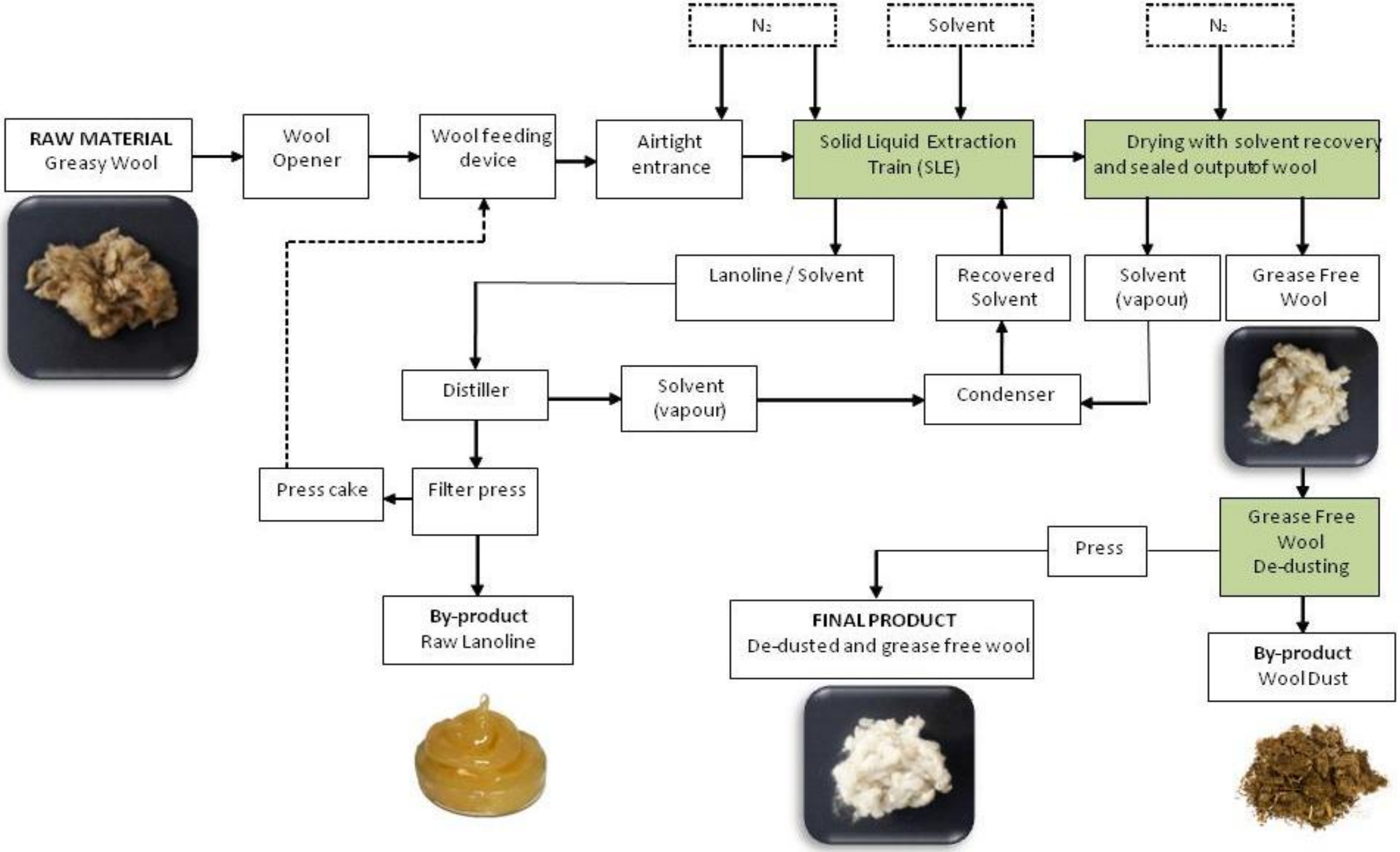
⇩

Their system is based on the De Smet Process with in-house company modifications

WDS concept approach



WDS process layout



WDS objectives

✓**Wool Dry Scouring (WDS)** project focuses on demonstrating a **new technology** to scour wool with total by-products recovery using solvent in a closed-loop system ⇨ replacement of the conventional wool water scouring

✓ High efficiency of **recovery of greasy wool components**: clean wool, wool grease (lanolin) and dirt (wool dust): by-products of wool with a market value.

✓Demonstration of **technical and economical feasibility** of the innovative technology to scour wool and recover by-products.

✓Reduction of **environmental impact**: reduction of water consumption, chemicals, energy, reduction of wastewater volume, wastewater with reduced waste load.

✓WDS targets fits with the priority areas for **LIFE+ Environmental Police and Governance** (waste prevention, recovery and recycling products)

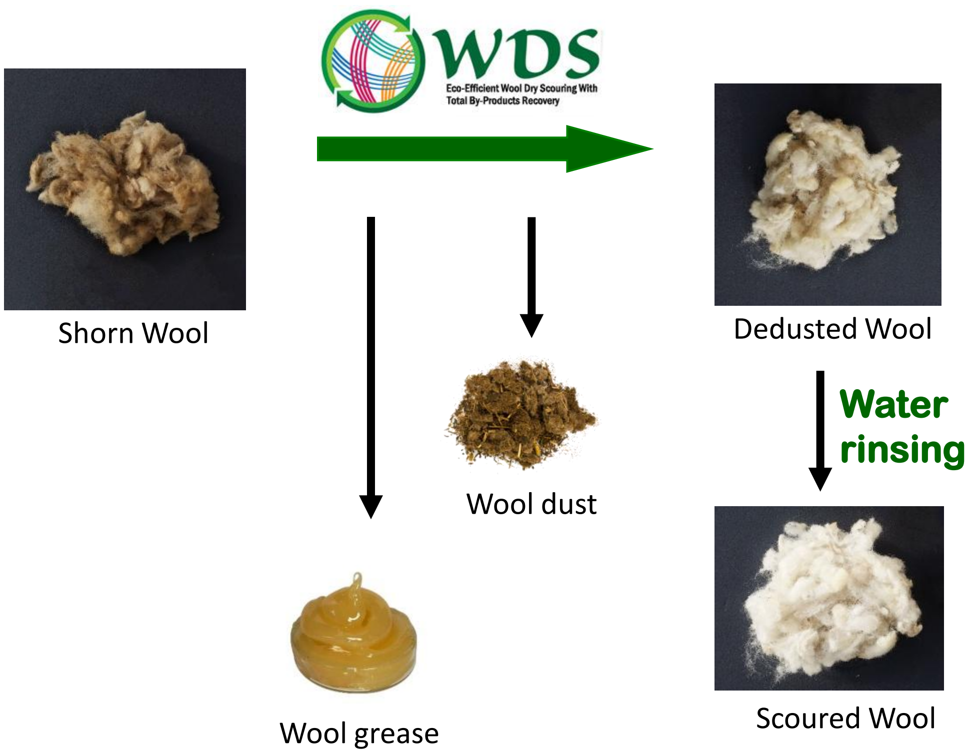
WDS optimisation at lab scale

(IQAC-CSIC)

Content

- WDS APPROACHING GLOBAL VISION
- WDS PROCESS AT LAB SCALE
- RESULTS

1. WDS APPROACHING GLOBAL VISION



OBJECTIVES:

-Study the variables with high influence on WDS process

-Definition the base of WDS process:

1- WOOL: homogenization to decrease their intrinsic variability

2-AQUOUS scouring process at lab scale to compare to our future results

1. WDS APPROACHING GLOBAL VISION

1. ORIGINAL WOOL CHARACTERIZATION

- Standard greasy wool raw material: **Type II Spanish Merino**
- Greasy wool homogenisation protocol
- Standard greasy wool characterisation:

  pH value of water extract (IWTO-2-96): 9.00

  Ash content (IWTO-19-03): 16.90 ± 0.22% (o.w.f)

  Ethanolic extract: 18.32 ± 0.93 % (o.w.f)

Figure: Type II Spanish Merino raw wool (greasy wool). Homogenisation

2. Optimization of aqueous wool scouring process at lab scale:

- Reason to apply the protocols:
  - on greasy wool to simulate the industrial wool scouring
  - on degreased wool (WDS wool) to simulate the WDS rinsing

- Different lab wool scouring protocols were defined
  - -protocols based on IWTO-19-03
  - -different protocols: with detergents,1/3 detergents, and without detergents

3. Previous lab studies on solvent extraction:

- Solvent screening (technical data: azeotropic mixtures, dielectric const., price, …)
- Initial tests performed with HEXANE (non polar), METHANOL (polar), ACETONE and ISOPROPANOL
- Solvent bath in erlenmeyer flask

➔ Complexity: high content of solvent imbibed in wool

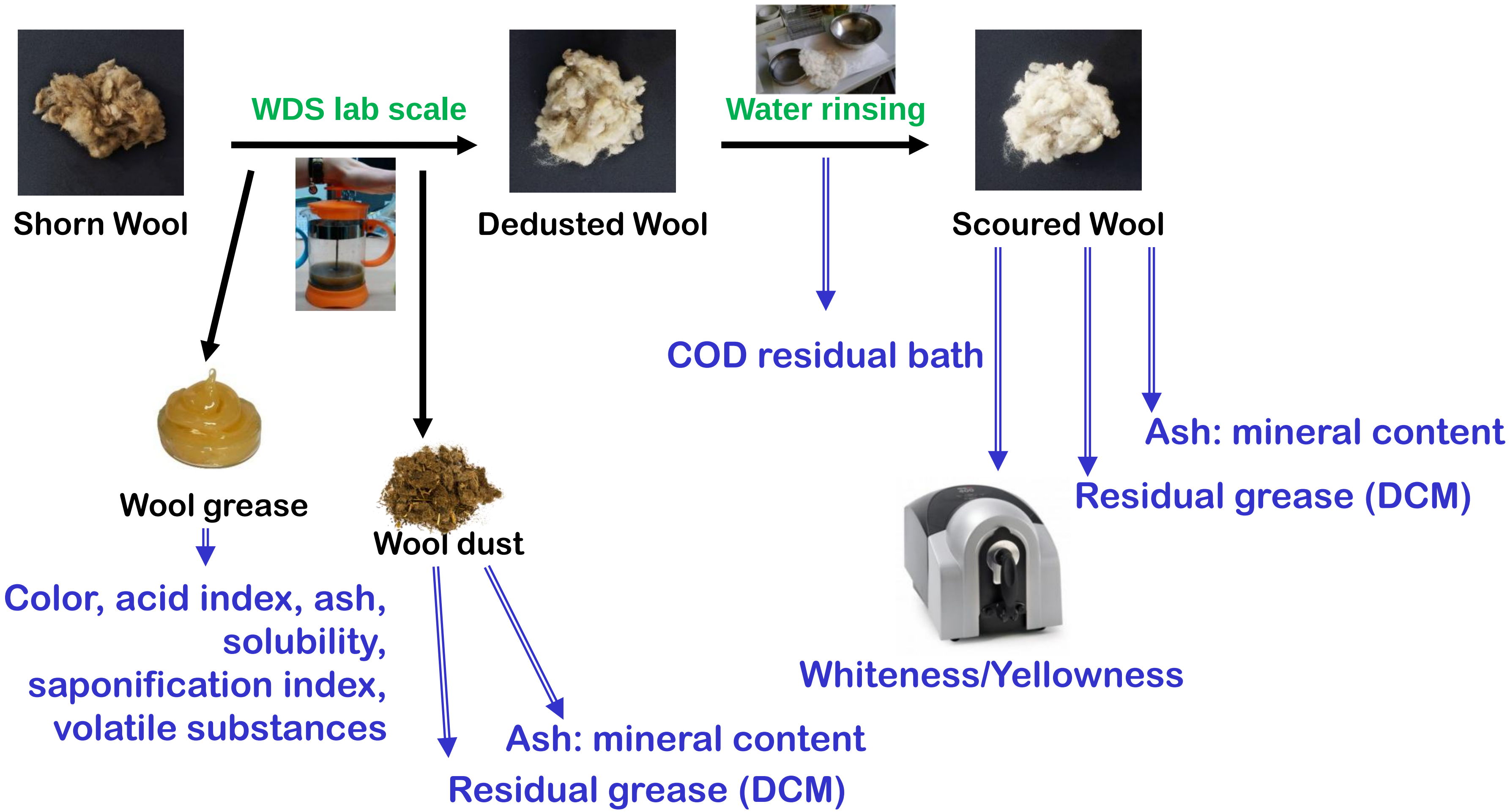
2. WDS process optimisation at lab scale

Variables:

- Previous wool conditioning (23ºC 50% RH or ½ 23ºC 50% RH)
- Bath ratio: 1/10
- Solvent treatment:
  - Solvent
  - Temperature (solvent boil point-10ºC, 25ºC, 35ºC or 45ºC)
  - Extraction number (2-4)
  - Time (10-30 min or 30-90 seconds)
- Aqueous rinsing:
  - With or without detergent

Results: Wool yield
Extracted grease (lanoline)
Wool dust
Whiteness/Yellowness
Residual grease on wool (DCM)
COD of rinsing baths
Water in solvent

2. WDS process optimisation at lab scale



2. WDS process optimisation at lab scale

SOLVENTS ⇨ different polarity

PREVIOUS LAB WORK: erlenmeyer flask

(hexane, methanol, acetone and isopropanol)

Define the WDS protocol at lab scale

DESIGN 1: tea pot + polypropylene bag

(hexane, methanol and acetone) ⇩ *dust retention*

Next: without bag

DESIGN 2: tea pot

(methanol + H_2O +sulfuric acid)⇨ *acid influence on suitine and water influence in solvent*

Next: apolar solvent

DESIGN 3: tea pot

(hexane, pentane and mixture 50/50)

3. RESULTS

Variables with high influence: Solvent

Extraction number

Temperature of extraction

WDS lab scale process: hexane extraction + aqueous rinsing

55% owf clean wool

20% owf wool grease (lanoline)

7-12% owf wool dust

COD of rinsing water ⇓

SOLVENT : HEXANE (apolar solvent)

EXTRACTION TEMPERATURE: 50ºC (higher grease extraction)

DRY PROCESS: at room temperature (due to bad influence on whiteness of high temperatures)

CRITICAL POINTS IN THE WDS PROCESS:

The development has made evident the complexity of the following critical points :

- Solid-Liquid Extraction
- Imbibed solvent recovery/drying

CONCLUSION OF LAB SCALE STUDY

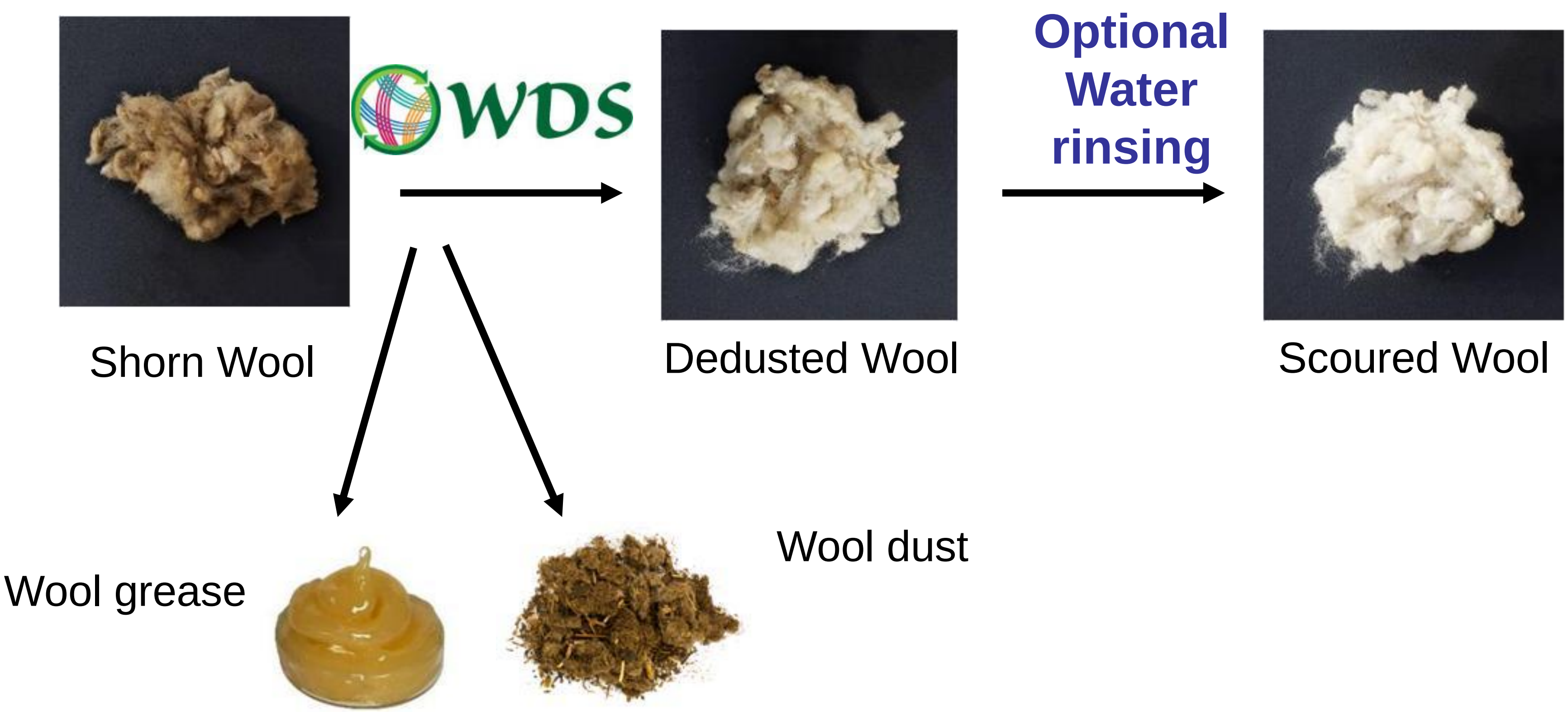
DESIGN AND CONSTRUCTION: REACTOR 1

- Deep study of solid retention of extracted wool
- Deep study of dry wool process avoiding solvent loss

WDS prototype

(RMT)

WDS concept approach



Content

- Continuous process (Initial)
- Batch process (Final)
  - Reactor 1
  - One-pot
  - Reactor 2

Extraction
+
Imbibed Solvent recovery

- Over-drying, De-dusting & Water rinsing

- Trials and results:
  - Comparative Industrial trial
  - Tannery Wool

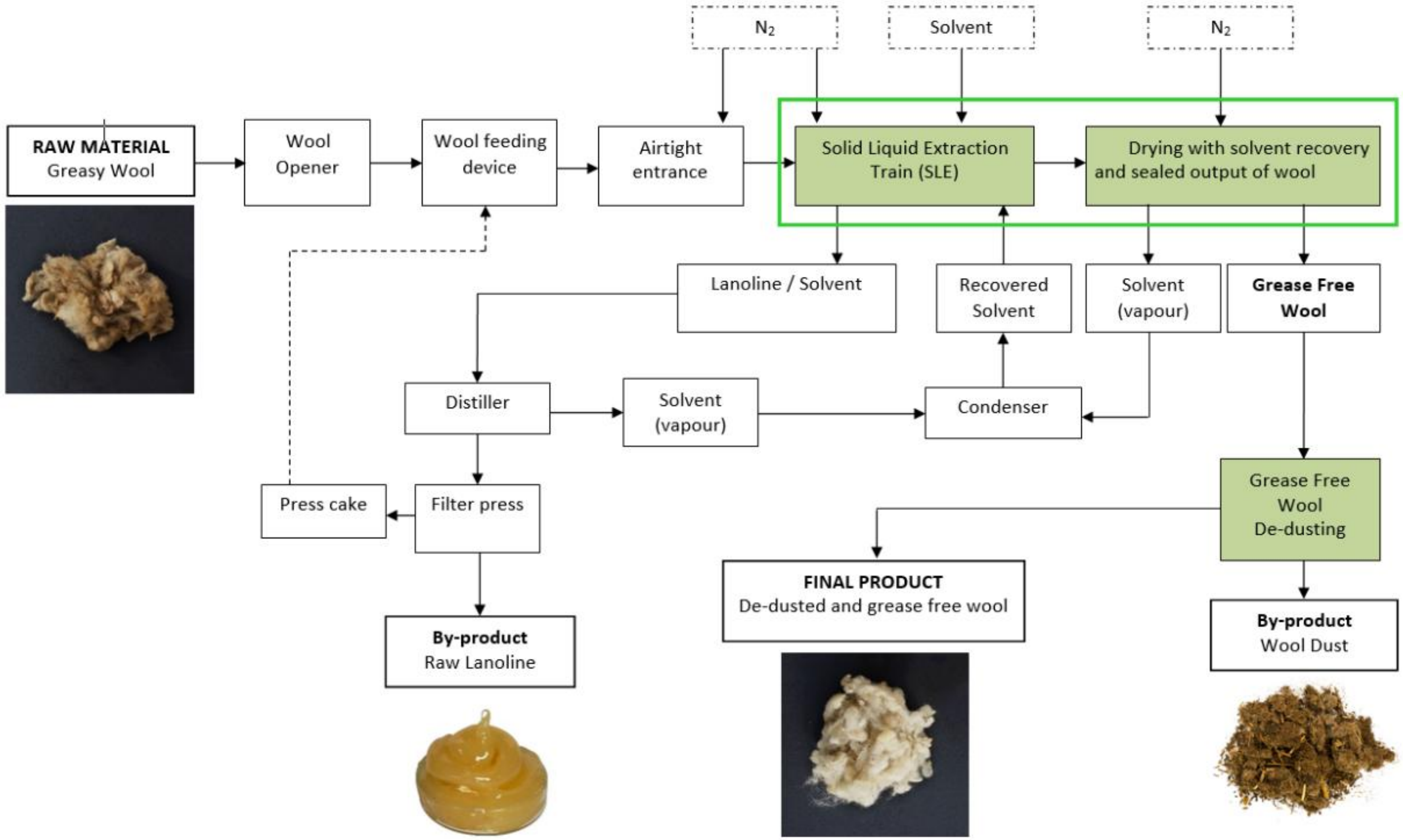
Process approaches:

- Initial: **Continuous** process (Abandoned)
- Final: **Batch** (Implemented)

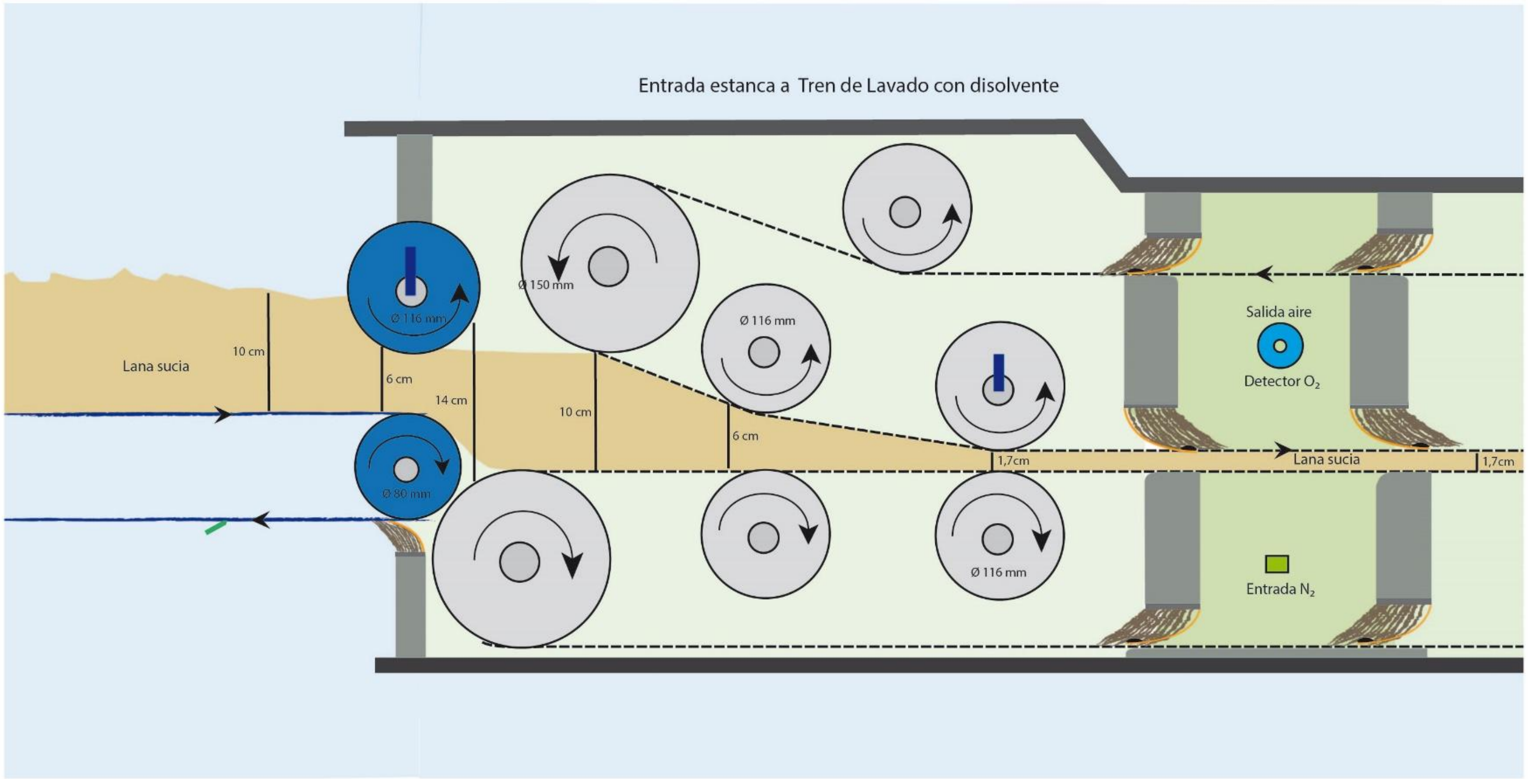
Steps:

- Entrance/exit confinement
- Solid-Liquid Extraction
- Embedded solvent recovery/drying

Continuous process



Entrance confinement: **Initial Concept**



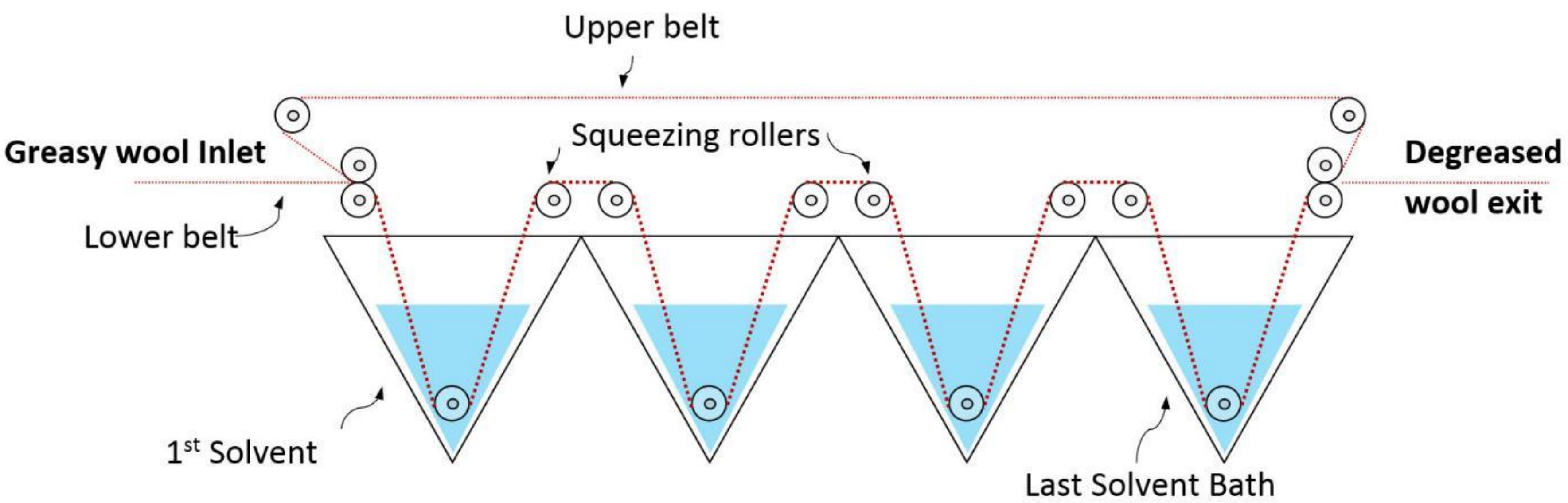
Solid-Liquid Extraction: **Initial Concept**

Compared to previous scouring systems:

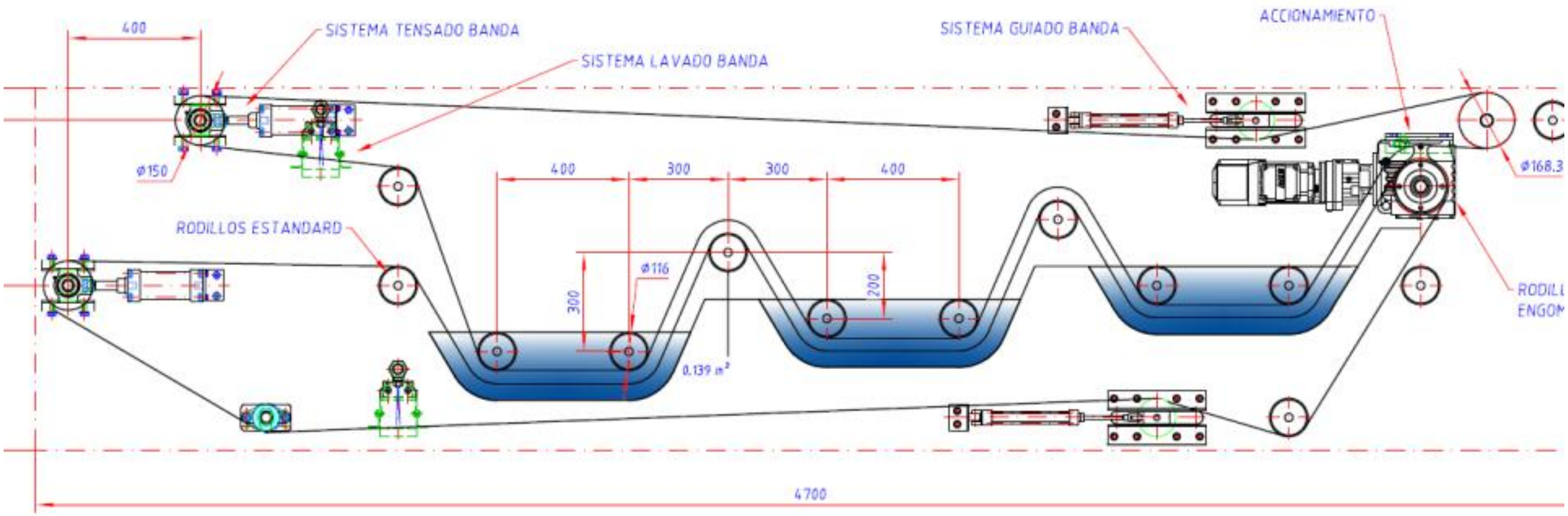
- Use of two conveyor belts and compressed wool to maintain dirt retained on wool. (Avoiding sedimentation)
- The belts are conceived to retain all the solids in-between. (Solvent extract free of solids)
- Squeezing generated by belt tension
- Fibres are kept static (avoids entanglement)

Solid-Liquid Extraction:

Initial Concept 1

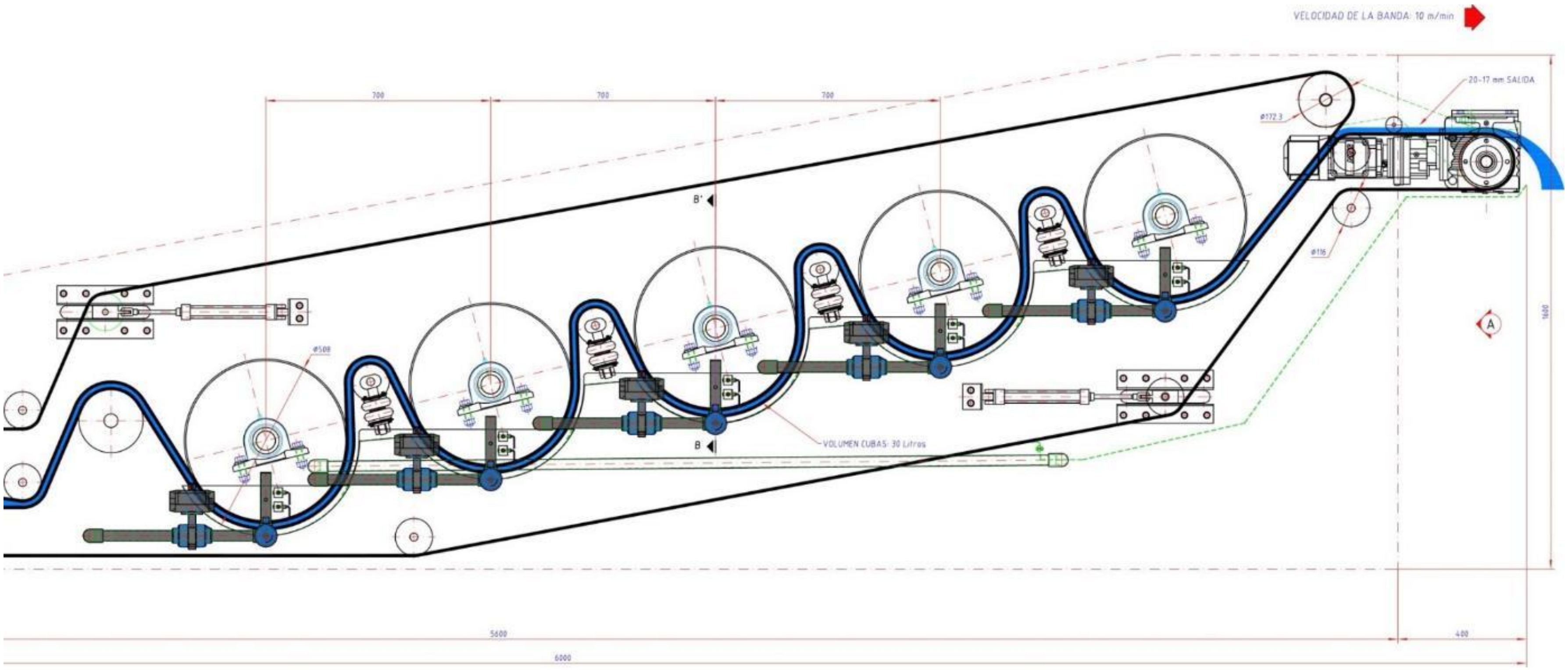


Solid-Liquid Extraction: **Initial Concept 2**



Solid-Liquid Extraction:

Initial Concept 3

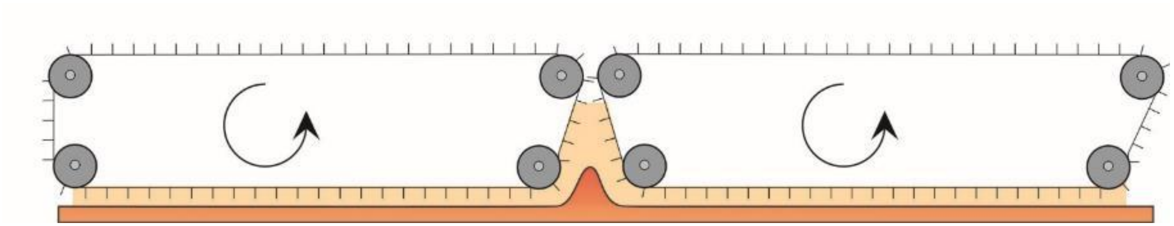


Embedded solvent recovery/drying: **Options**

- Different possibilities: (to provide energy)
  - Conductive
  - Convective
  - Microwaves

Embedded solvent recovery/drying:

Conductive drying



Initial Concept 1

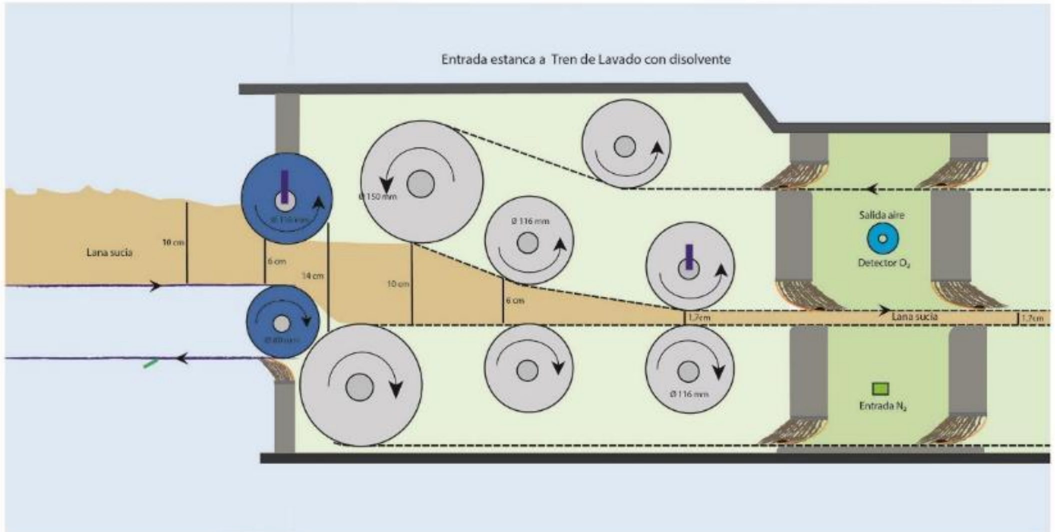
Initial Concept 2

Continuous process
Key points to solve

- Entrance/exit confinement
- Solid-Liquid Extraction
- Embedded solvent recovery/drying

Entrance/exit confinement

Not tested → Technical risk



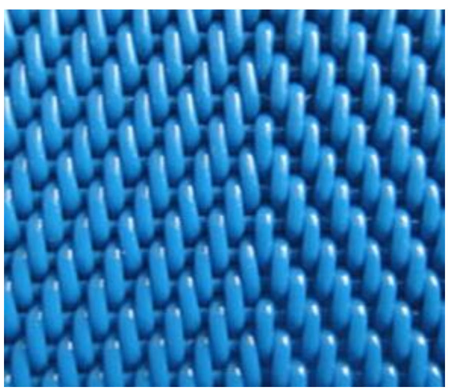
Risk of explosive atmosphere, limited but present

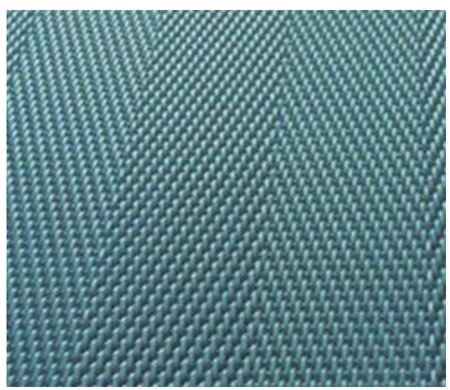
Solid-Liquid Extraction (Issues)

Wool dirt content (fines) pass through conveyor belt band.

Not Expected

¡Big problem!





Solid-Liquid Extraction (Issues)

Extract when vacuum filtered at 10µ blinds soon the filter.

Embedded solvent recovery/drying

- The drying system had to be design from zero. While innovative solutions were invented → high technical risk

Initial Concept 2

- Key issues in the solvent recovery/drying stage:

- Avoid explosive atmosphere
- Avoid wool colour fixing and toasting
- Avoid solvent losses

To separate the lanolin and solvent from the fines; a serious issue.

The continuous process becomes **not viable**

CRISIS

WDS rethink

Same principle:

"Greasy wool solvent degreased and over-dried liberates easily the non fibre material as a fine dust"

Same objectives:

- Full wool grease recovery
- Full solvent recovery
- Recovery of suint & dirt directly as a solid material (dust)

By a different process

Batch process:

Based in a reactor carrying out:

- -Wool pressing
- -Degreasing with solvent
- -Fines retention
- -Imbibed solvent recovery

Entrance/exit confinement:

- Easy closing (no continuous entrance and exit)

Imbibed solvent recovery/drying

New idea: Provide energy by water vapour

Water vapour heats the wool and evaporates imbibed solvent

Working with water vapour (≥100ºC) Wool shows undesired colour fixation

Imbibed solvent recovery/drying

New Idea: How to avoid colour fixation?

- Solvent boiling point ↓
- Apply partial vacuum allows working at lower solvent boiling temperatures

Colour fixation avoided → Desired whiteness preserved

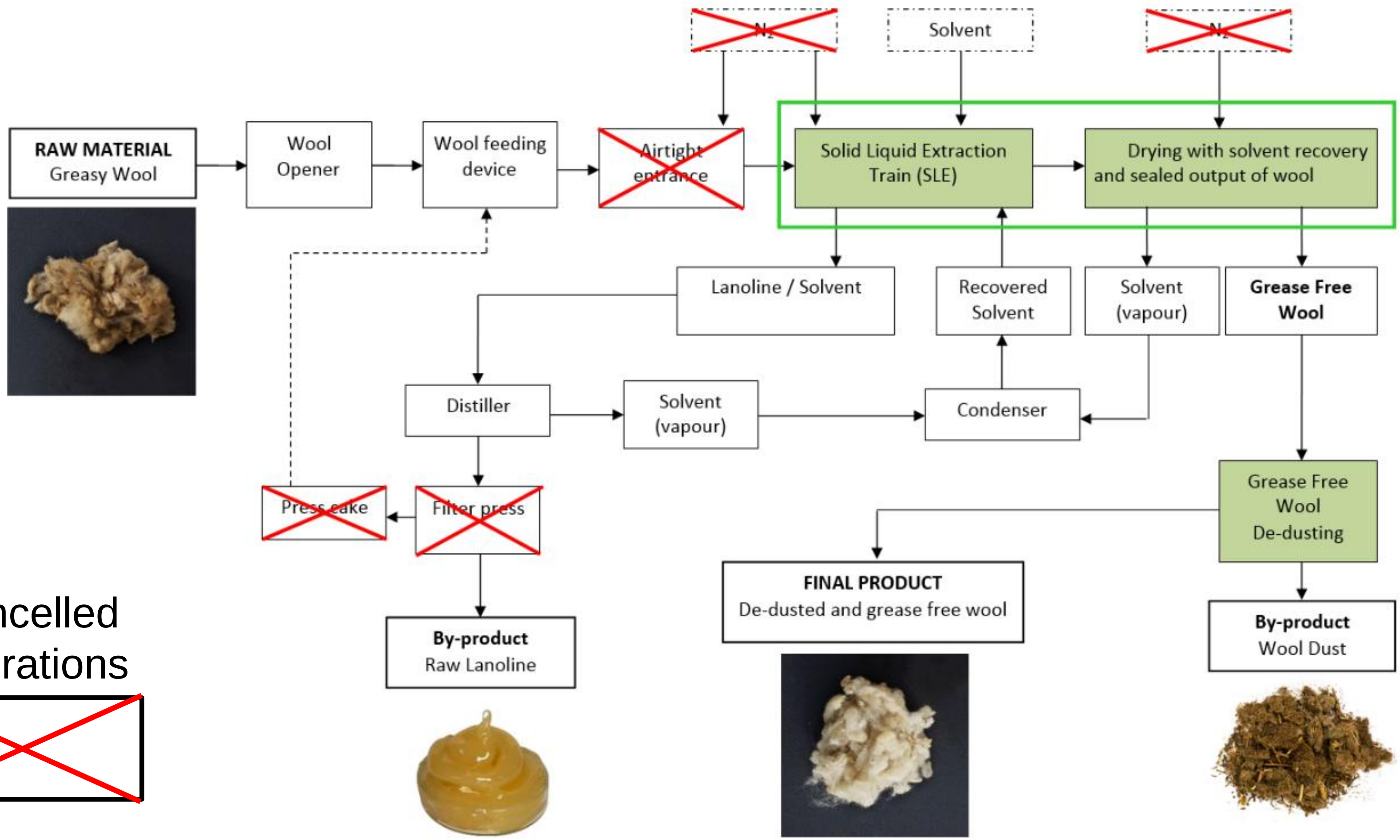
Solid-Liquid Extraction

By consecutive steps:

Fill and empty of solvent bath each time with less grease. (Counter-current)

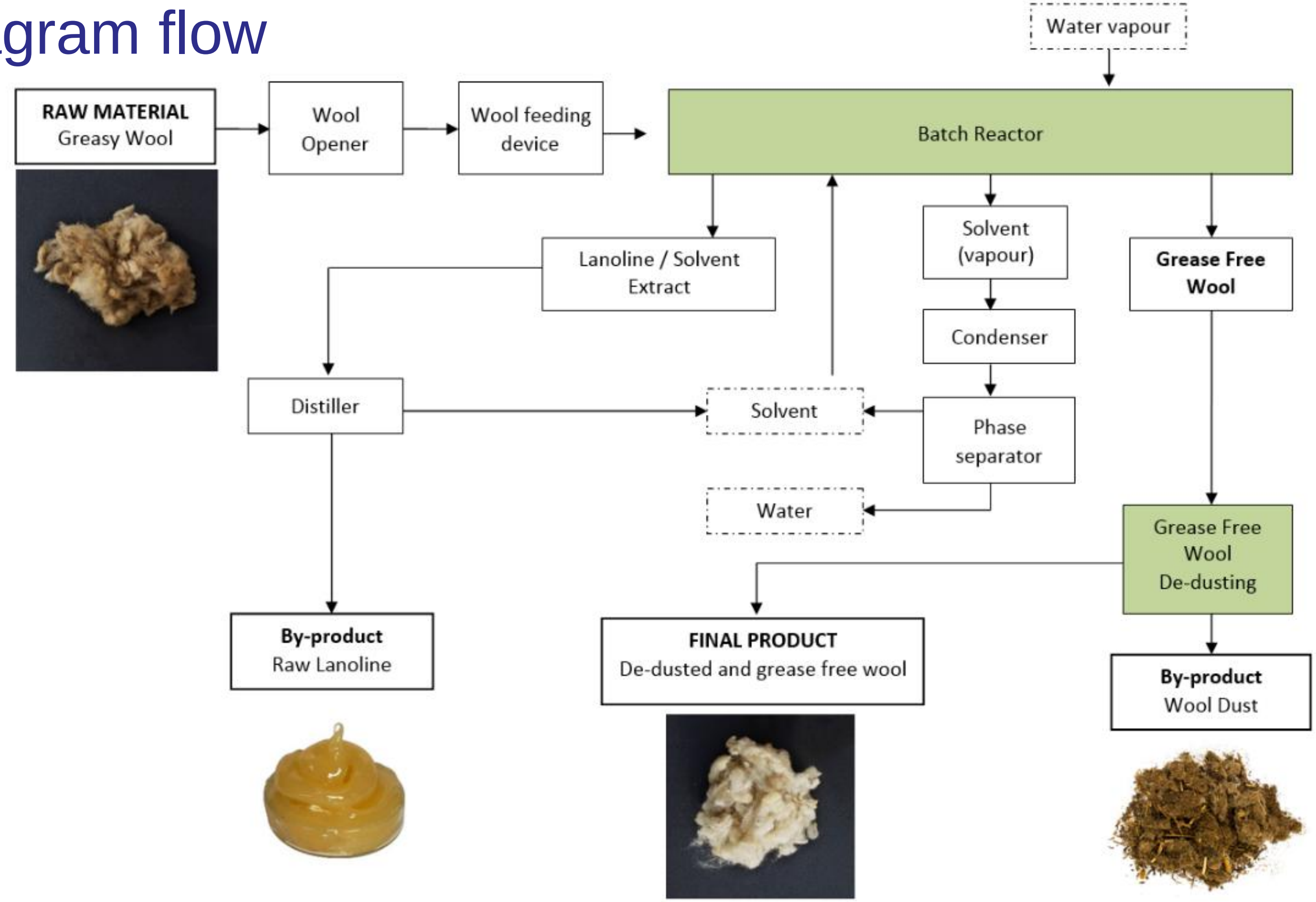
WDS
Process diagram redefined

Batch process



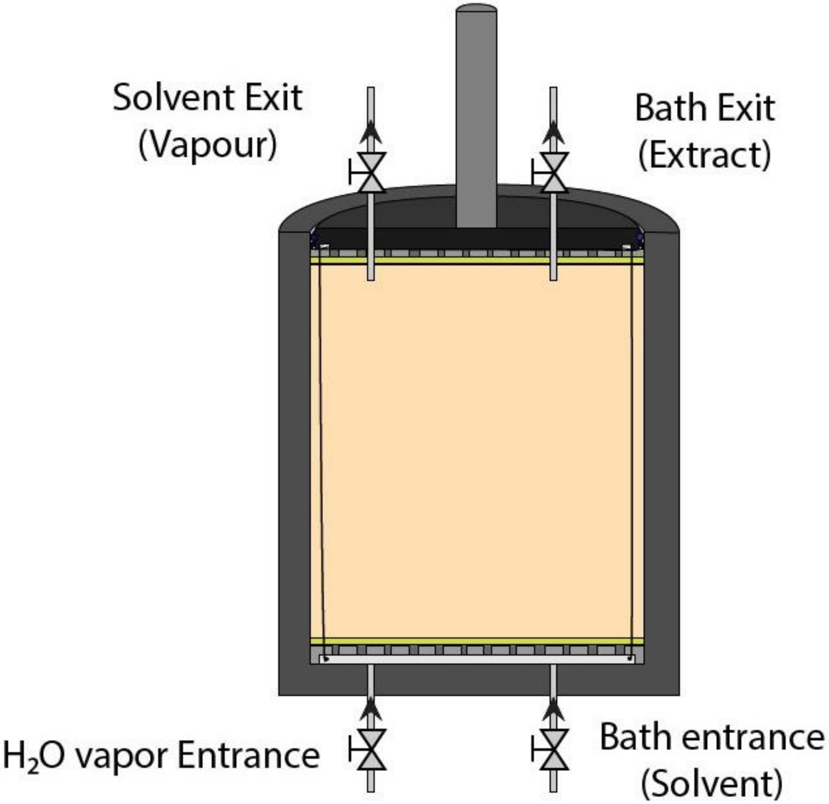
Cancelled operations

WDS Diagram flow



Batch

Initial Concept

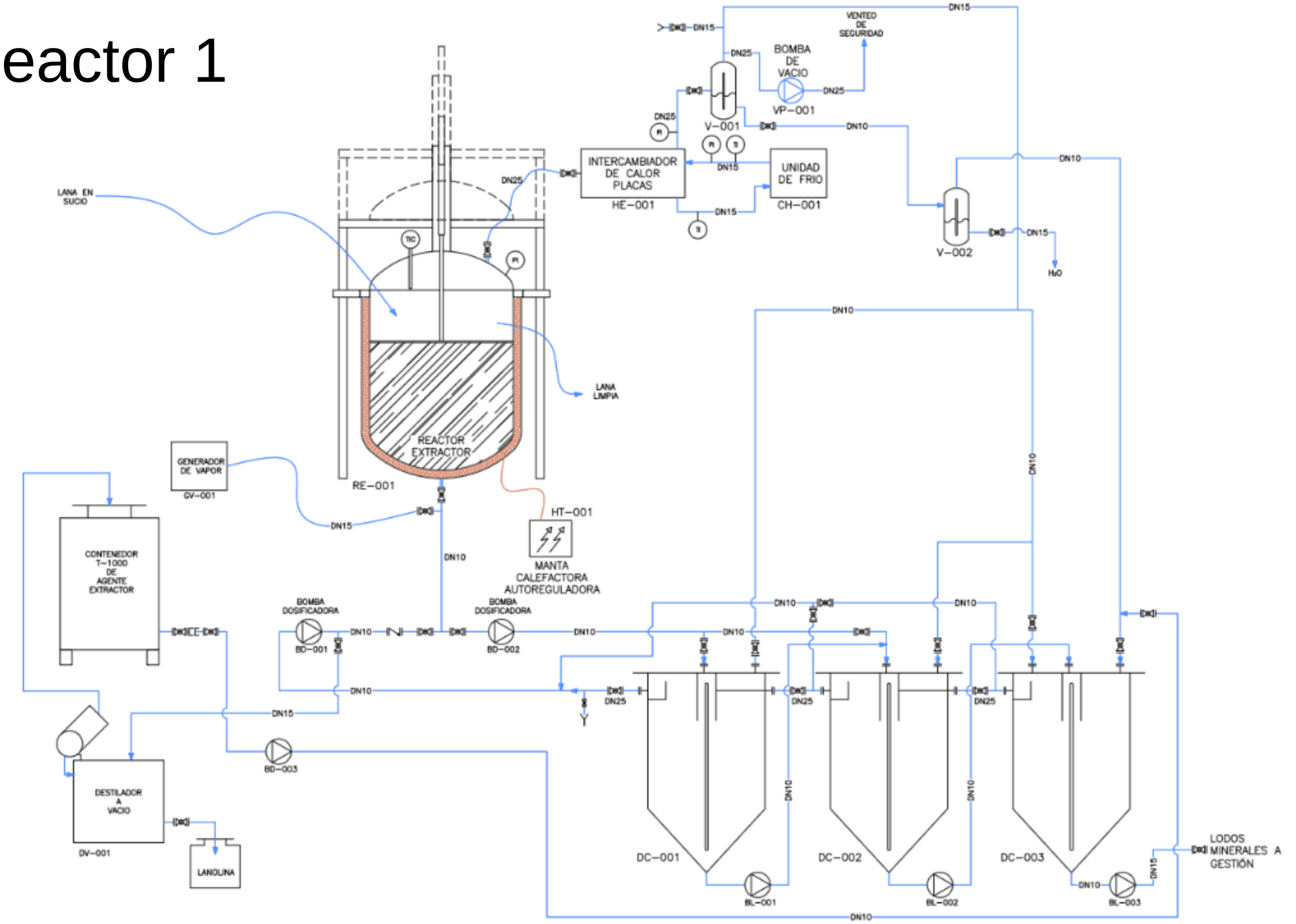


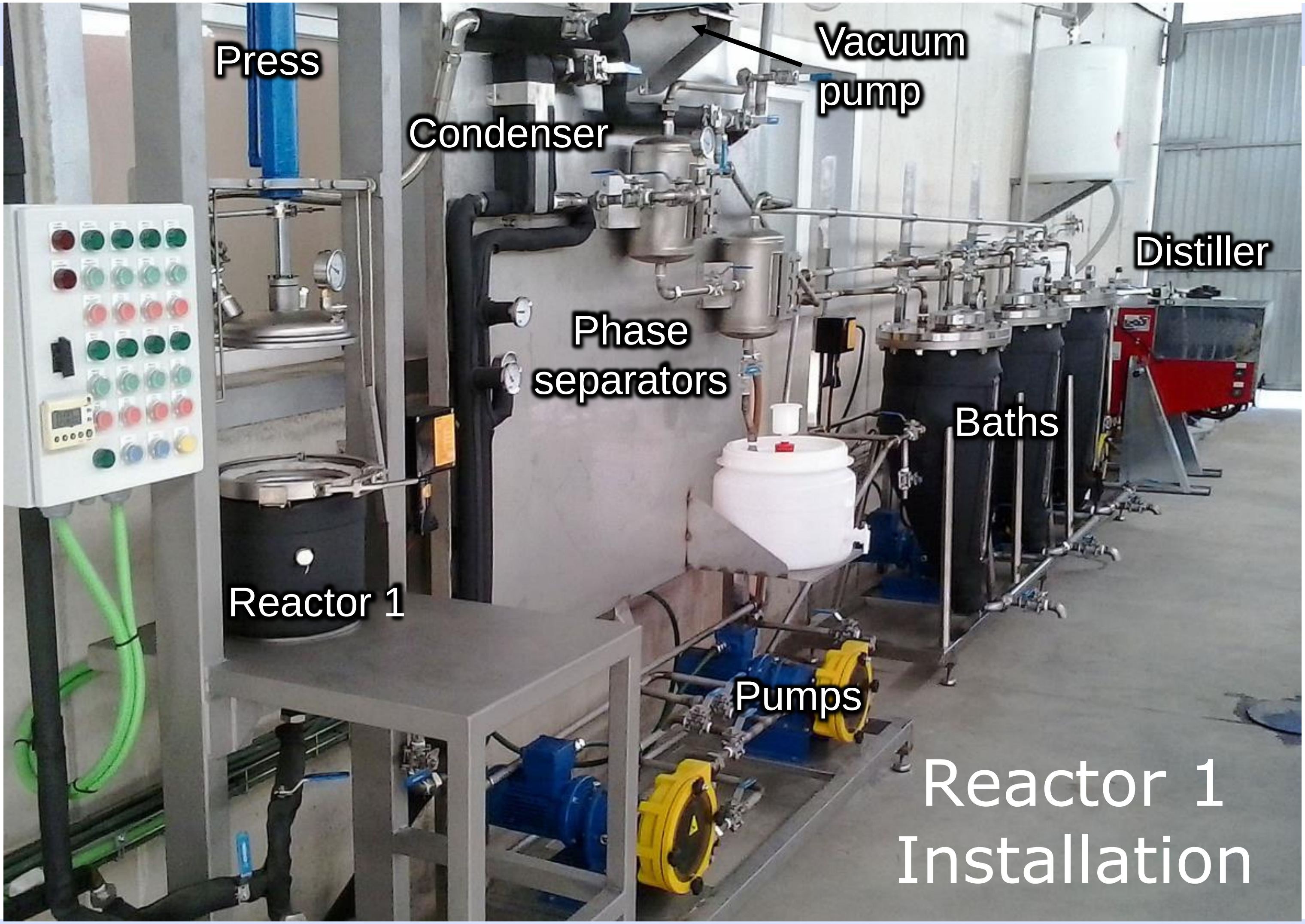
Batch concept

- Loading
- Press
- Filling and emptying of different bath
- Vacuum + Water vapour + Condensate recovery
- Air injection (cools down and assists emptying)

WDS Reactor 1

WDS layout: Reactor 1




Press
Condenser
Vacuum pump
Phase separators
Distiller
Baths
Reactor 1
Pumps
Reactor 1 Installation

Batch process

Reactor 1

Baths

Batch process

Chiller

Steam generator

Distiller

Reactor 1

Reactor 1

Pressing step

Reactor 1

Without container

With container

WDS Reactor 1

Issues:

- Solvent removal incomplete
- Grease extraction incomplete and not homogeneous
- Fines in the extract
- High water content in condensates

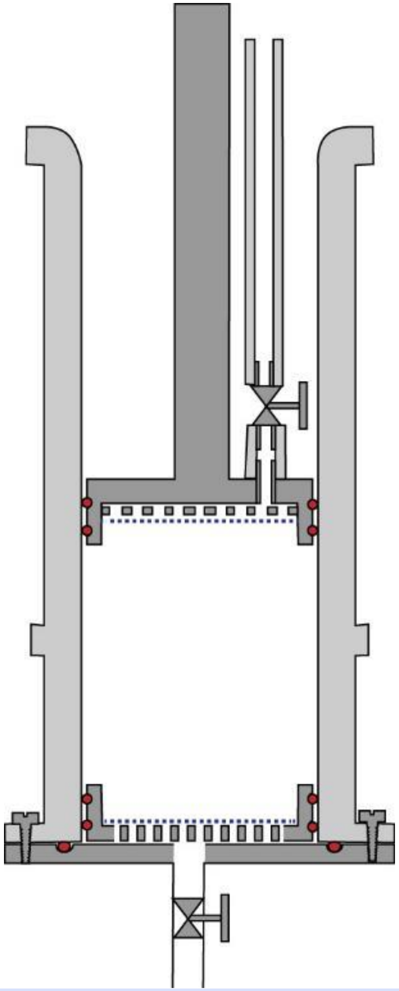
Extract & Wool grease with high content of fines

Reactor 1 Extract

Reactor 1 Wool grease

Reactor 1 → Unsuccessful results

New lab equipment to test potential solutions → One-pot



One-pot (Lab equipment)

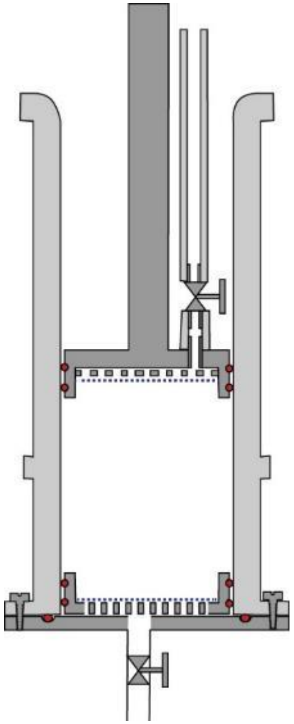
Concept:

Syringe containing wool with filters and diffusers

One-pot (Lab equipment)

Functions:

- Wool Press
- Solvent pumping (high flow)
- Homogenous flow (solvent and vapour)
- Filters + Wool Autofiltring effect



One-pot (Lab equipment)

Solving previous issues:

√ Solvent removal incomplete **solved**

√ Grease extraction inhomogeneous **solved**

√ Fines in the extract **Big improvement but still present**

One-pot First Results

Negative: Despite a large amount of fines are retained, a fraction goes to the solvent extract.

Reason: suctioning solvent liberates fines

Problem: Fines in the solvent extract

New idea: Solvent flow through pressed wool (by External pump)

Tested: One-pot + peristaltic pump

Finally…

It works!

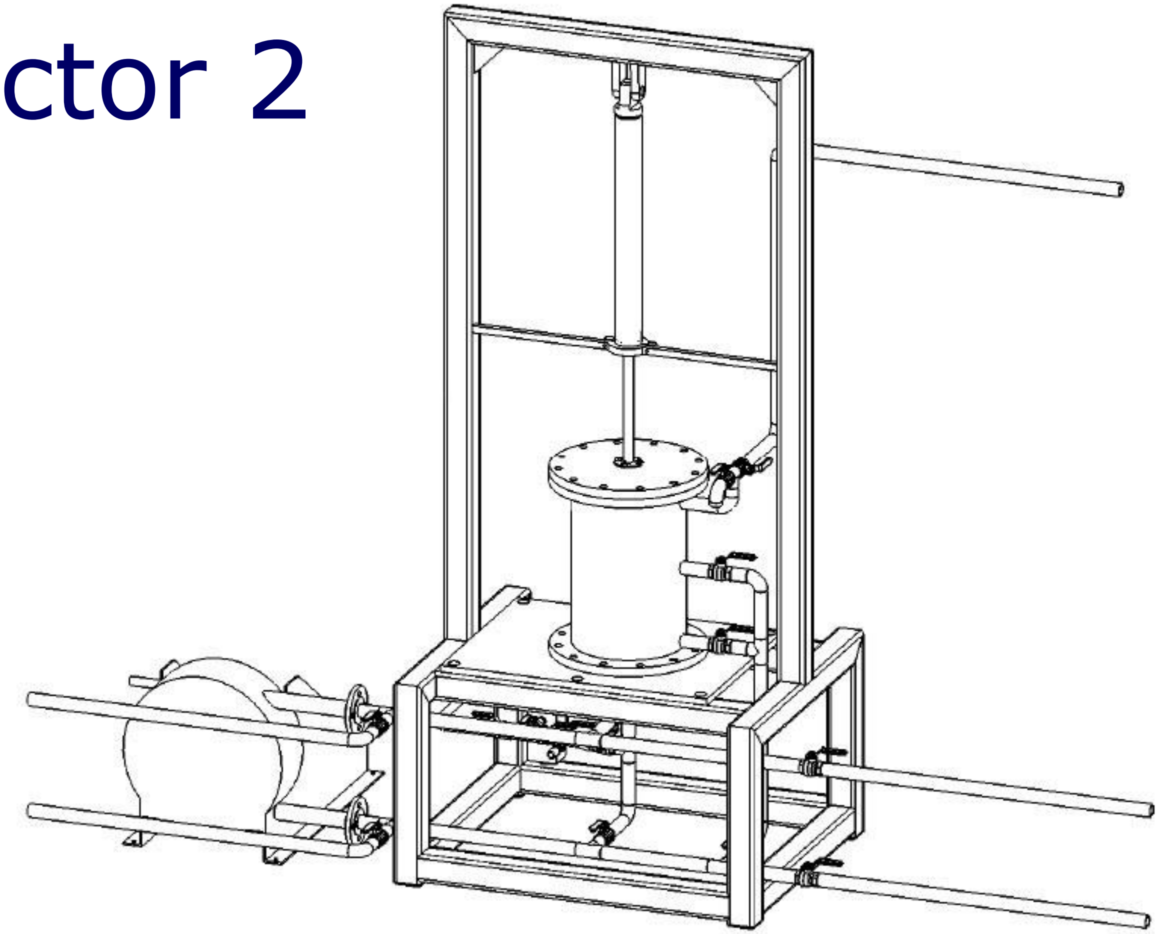
Fines are retained

New Reactor 2

Implementing one-pot learnings:

- √ Solvent removal incomplete **solved**
- √ Grease extraction inhomogeneous **solved**
- √ Fines in the extract **solved**

New Reactor 2

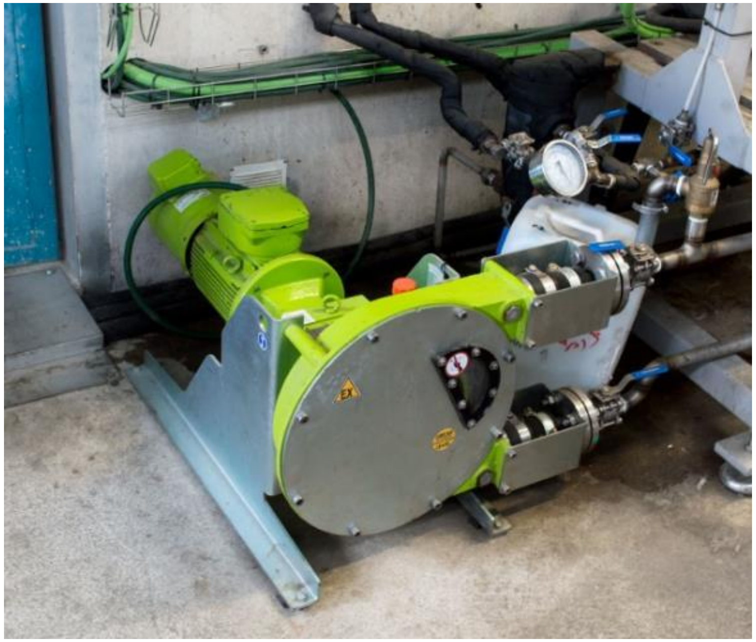


Reactor 2

- Different:
  - Reactor 2
  - High-flow-rate peristaltic pump
  - 3 Baths of clean solvent → to simplify trials
- Same: Distiller, Vacuum and Chiller

Batch process

Reactor 2 Installation Overview



Peristaltic Pump

Post-treatments

“Greasy wool solvent degreased and over-dried liberates easily the non fibre material as a fine dust”

Effect of over-drying on wool dust recovery

- Over-drying
- De-dusting
- Water rinsing (scouring)

Effect of over-drying on wool dust recovery

Lab trials on shorn wool

Reference — **1A Traditional Water scouring**

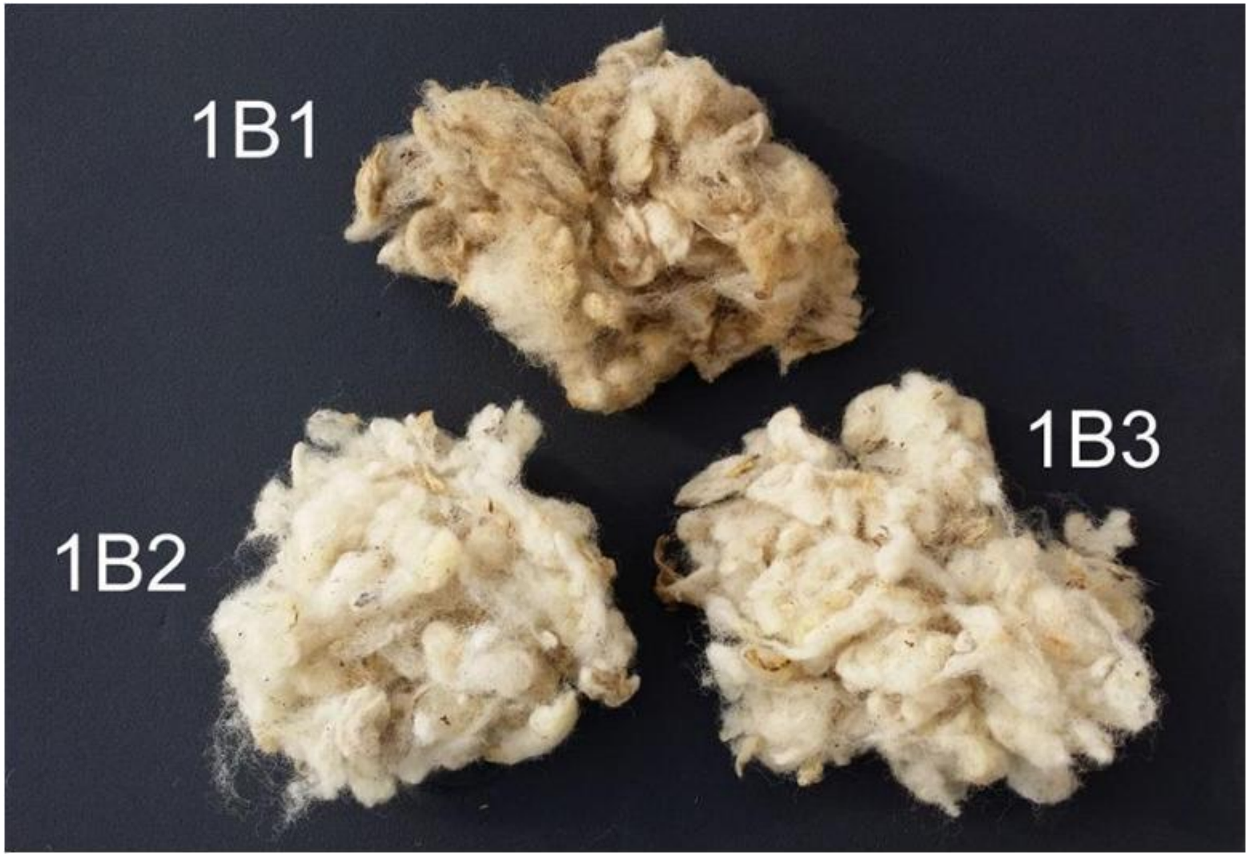
WDS
- **1B1 Dried at ambient temperature**
- **1B2 with over-drying at 60ºC**
- **1B3 Totally dried (over-drying at 100ºC)**

Trials

Effect of over-drying on wool dust recovery Wool: Shorn wool (Spanish origin, Type IV)				
	1A	1B1	1B2	1B3
Initial wool grease %	9,3%			
% Recovered grease	-	8,2%		
% Grease in wool after extraction	-	**1,3%**		
Post-treatment	-	Drying at room temperature	Drying at 60 ºC & de-dusting	Drying at 100 ºC & de-dusting
% Wool Humidity (post-treatment)	-	14,2%	3,3%	0,0%
% Wool dust over initial weight	-	**1,7%**	**20,3%**	17,4%
% COD Reduction vs water scouring		**40,5%**	**74,7%**	**72,9%**
% Residual grease in scoured wool	**1,80%**	**1,03%**	**0,32%**	**0,39%**
Scoured wool Whiteness	**47,4**	**51,6**	**51,7**	**51,0**

% over initial wool weight

De-dusted wool



Over-drying

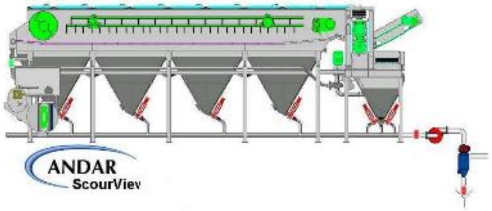
Driers

De-dusting

Water rinsing-scouring

- Lab scale (RMT)

- Industrial Scale (Tavares)



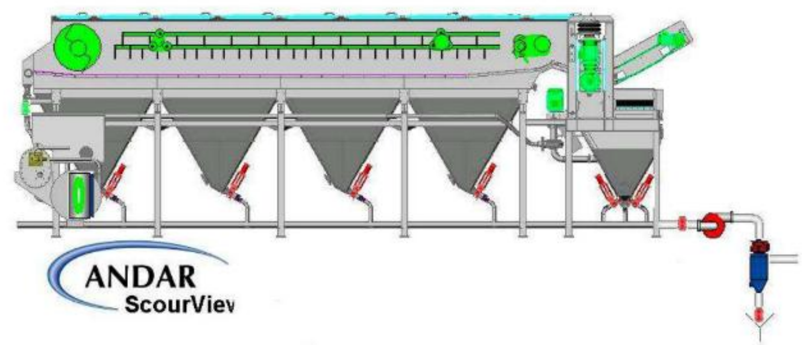
Water rinsing-scouring: Lab scale

4 Baths of water
Discontinuous process

	Traditional Water scouring (reference)	WDS water rinsing
1st Bath:	50ºC + 0,5% Sodium carbonate + 0,1% Detergent	50ºC + 0,5% Sodium carbonate + 0,05% Detergent
2nd Bath:	50ºC + 0,1% Detergent	40ºC
3rd Bath:	40ºC	30ºC
4th Bath:	20ºC	20ºC

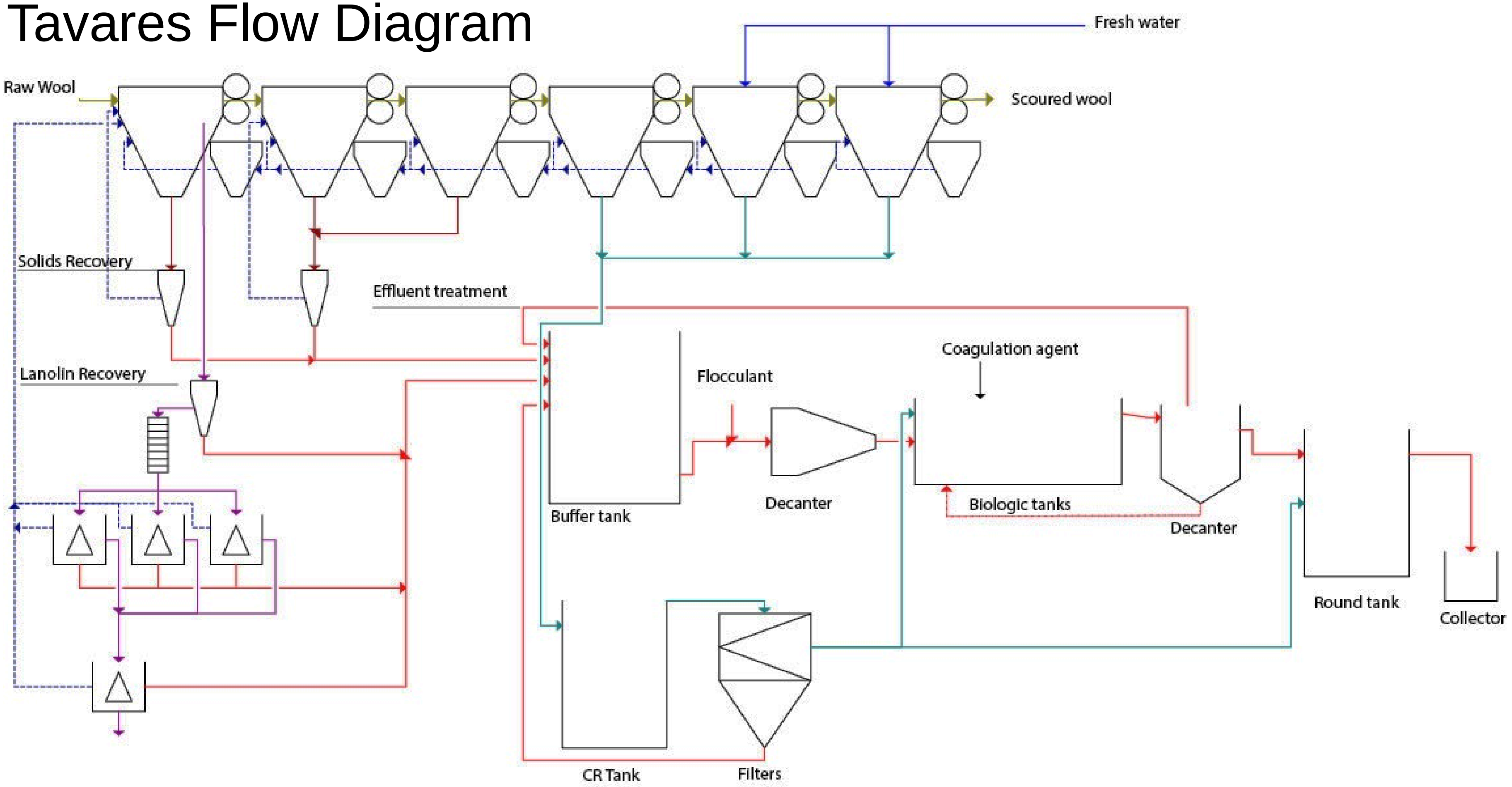
Water scouring: Industrial scale

Bath train at Tavares



1st Bath at Tavares

Tavares Flow Diagram



Trials and results

Comparative Industrial trial (Reactor 1)

Shorn Wool: Spanish Merino Type II

Traditional Water scouring (Tavares - Andar)	VS	**WDS** (RMT – Reactor 1) + **Water scouring** (Tavares - Andar)

Comparative Industrial trial (Reactor 1)

Analysis of:

- Wool quality & COD
- Combed wool quality (Top)
- Grease
- Wool dust

Comparative Industrial trial (Reactor 1) Shorn Wool: Spanish Merino Type II		
	Traditional Water scouring 2A	WDS + Water scouring 2B
% Initial wool grease	14,4%	
% Recovered grease	-	11,9%
Post-treatment	-	Drying at 60 ºC & de-dusting
% COD Reduction vs water scouring		**76,4%**
% Residual grease in scoured wool	1,15%	**0,64%**
% Total Wool dust	1,81%	**23,6%**
Scoured wool Whiteness	48,6	**52,6**

% over initial wool weight

Combed wool (Top)

Trial	Fibre Ø Microns		Hauteur (H)	Barbe (B)	CVH %	CVB %	% fibres < 25 mm	% fibres < 40mm	5 % Higher Length	1 % Higher Length
	Airflow	Laser Scan	mm	mm	%	%	%	%	mm	mm
Traditional Water scouring 2A	23,3	22,6	44,0	53,4	46,1	41,3	23,8	59,1	75,5	90,2
WDS + Water scouring 2B	22,6	22,9	42,6	53,4	50,3	42,1	21,5	50,5	87,0	102,3

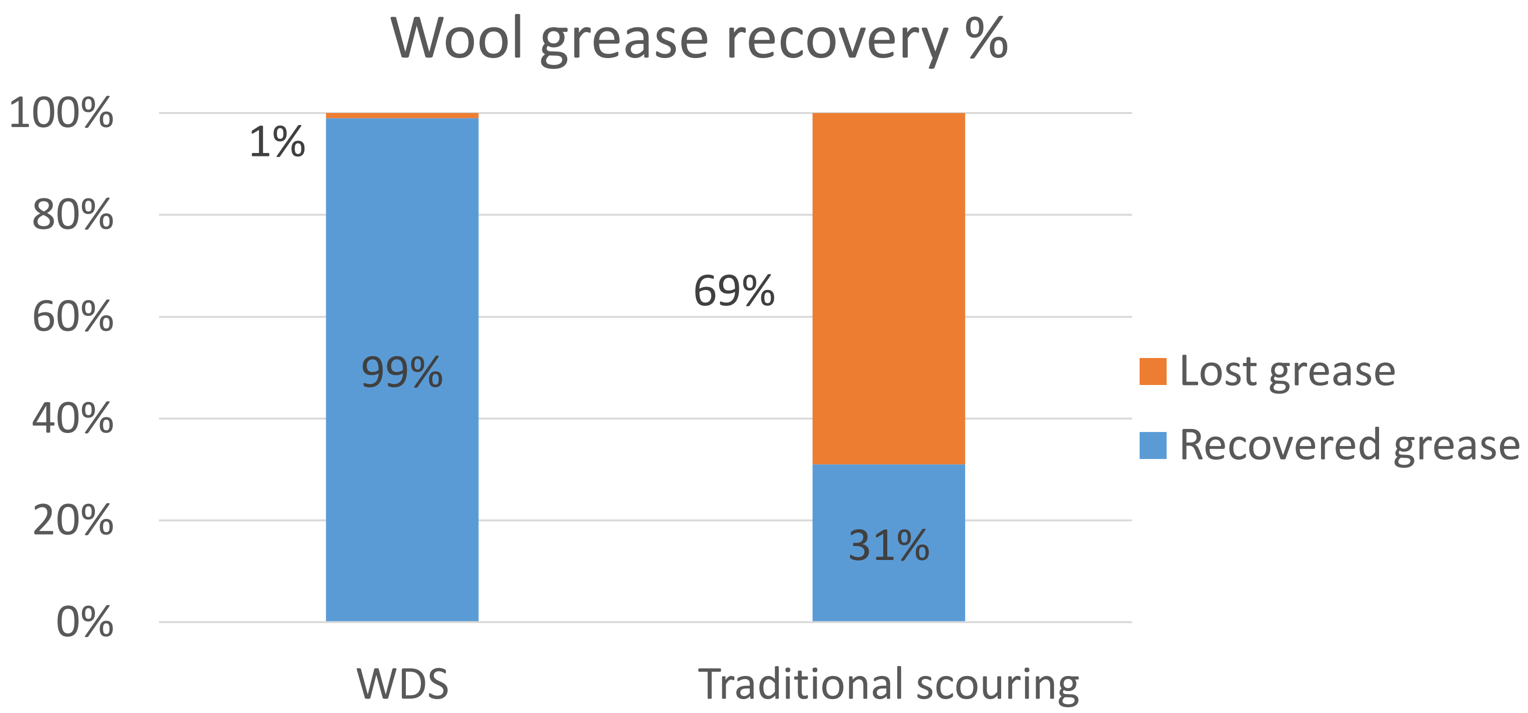
Combed wool (Top)

Fibre diameter different values depending on method → Possibly WDS favours closed scales → Less air resistance.

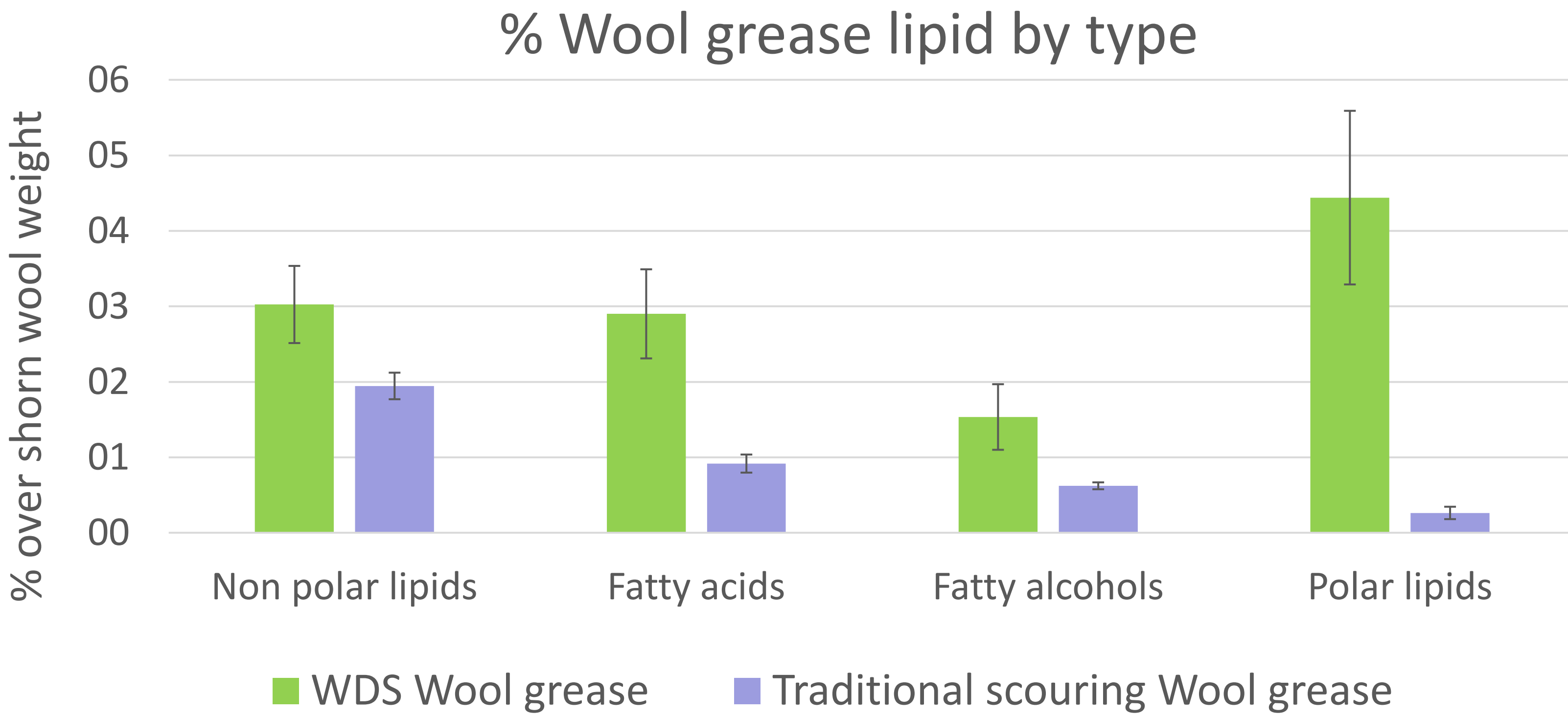
WDS Process maintains long fibres better than water scouring.

5% Higher length: 75,5mm vs 87,0mm

Wool grease: Yield comparison



Wool grease Lipid Characterization: (TLC-FID)



Wool grease:

- **WDS** recovers a higher proportion of all grease components. Detergents Free

- **Traditional Water scouring**
  - Lower recovery of grease and much lower on polar lipids → Reason: polar lipids retained in scouring water

Wool dust characterization

Composed of:

K: Suint

C: Suint + Vegetable matter

N: Wool protein, dead skin cells…

Plus mineral content

Wool dust can be used as organic fertilizer. It contains N, C, K and it doesn't contain noticeable amounts of toxic heavy metals.

Best grade natural fertilizer (Class A)

Careful: Seeds should be dead

Heavy Metal Fertilizer limits Class A	
Metal	**Maximum**
Cadmium	0,7
Copper	70
Nickel	25
Lead	45
Zinc	200
Mercury	0,4
Chrome	70

(Amounts on WDS wool dust always less than half of a Class A limit)

Tannery Wool trial

Purpose:

Test WDS on suint and dirt free wool

Trials

Wool: Tannery Wool (Skin depilation, English origin)		
	Traditional Water Scouring	WDS
Initial wool grease %	6,5%	
% Recovered grease		5,35%
Post-treatment	-	Dried 20ºC
% DQO Reduction vs water scouring		**74,8%**
% Residual grease vs water scouring	2,72%	**0,65%**
% Clean wool	91,2%	89,9%
Whiteness	50,0	**56,2**

% over initial wool weight

Tannery Wool trial

- WDS recovers grease in Tannery Wool (Traditionally it’s not recovered)

WDS Water rinsing step just slightly improves wool appearance and can be avoided

WDS solvent losses

- <3% Prototype
- <1% Expected for full industrial level

% over raw wool processed

Industrial Implementation Approach

Next steps

Separate Pressing stage

For higher production efficiency split the wool densification operation from extraction.

How ?

Making containers or wool bales adapted to be placed inside the industrial extractor.

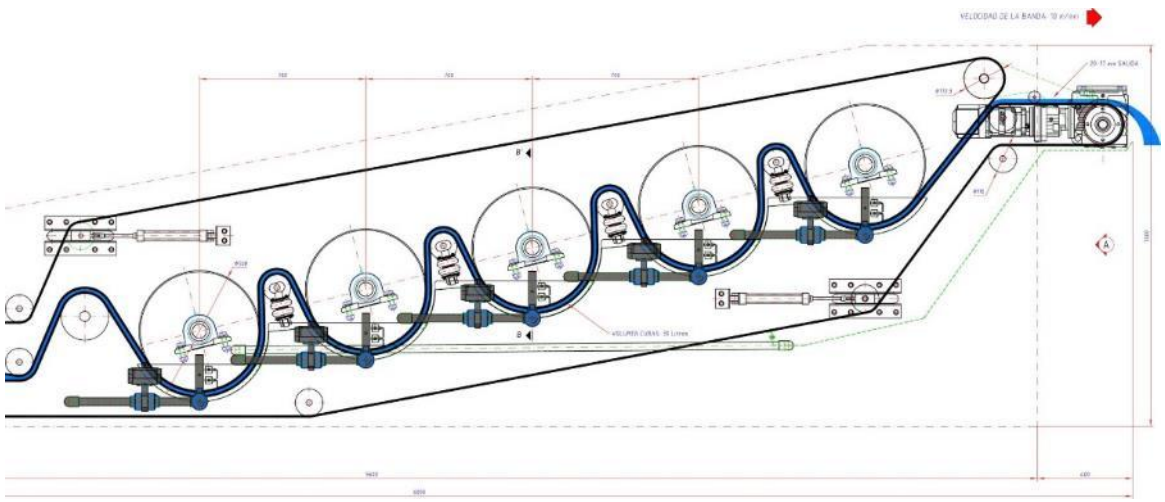
Optional water rinsing

Wool could be combed or carded and later scour the yarn. Final rinsing could also be done during the dyeing stage.

If water rinsing is required →

WDS Water rinsing

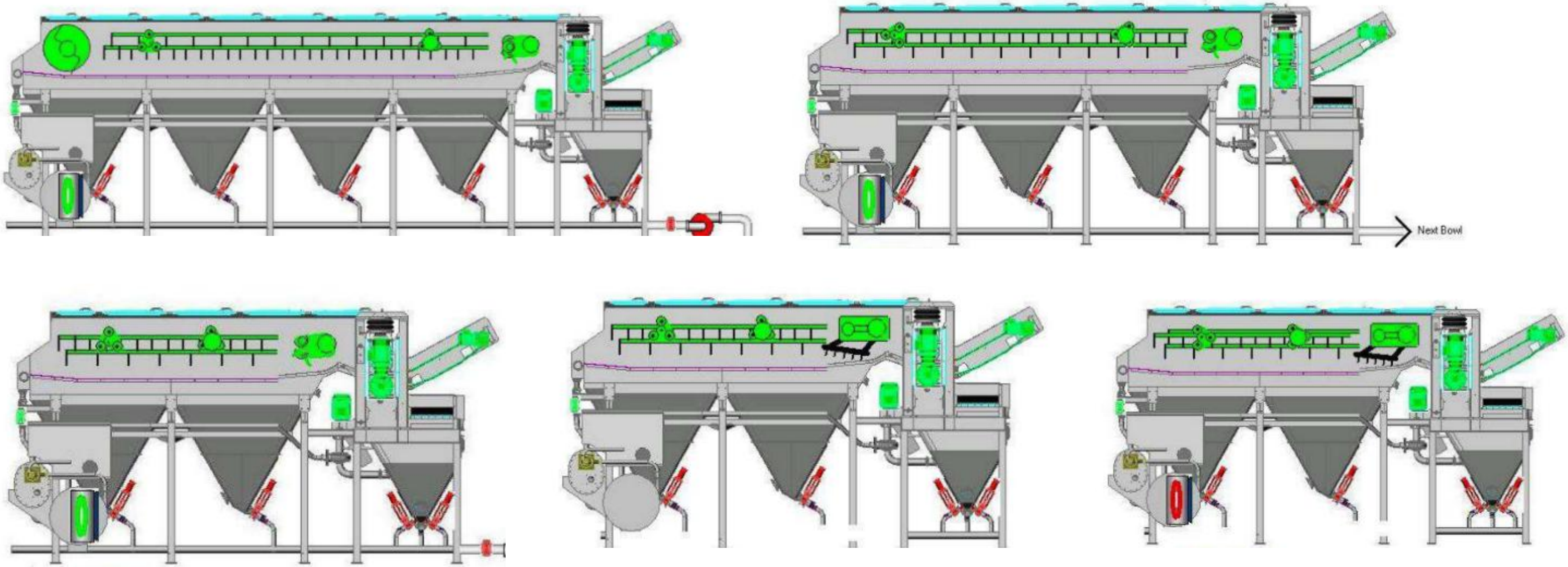
Counter current and compact equipment allows high concentrate effluent



5 Baths

High efficiency
smaller investment

Traditional scouring



ANDAR ScourViev

5 Baths comparison

Advantages WDS Rinsing concept applied

- High concentration effluent
- Energy Efficient using multi-step evaporator
- Zero waste water generation (Closed water loop system)

The highly concentrated effluent can be mixed with wool dust to create an excellent fertilizer

Economic Overview

Cost drivers change

WDS **VS** **Traditional water scouring**

Economic Overview

WDS cost drivers change vs traditional water scouring

			By item	By segment
Incomes	*Wool*	Quality	+	√ √ √
		Yield	=	
	By-products	Wool grease	+++	
		Wool dust	++	
Expenses	*Chemicals*	Detergent	--	√
		Soda	--	
		Solvent	+	
		Labour	= / +	√
		Energy	= / --	
		Water	---	
		Waste treatment & Disposal	---	
		Investment depreciation (New plant)	-	

WDS Economic performance clearly positive

Semi-industrial WDS shows:

- **Enhanced Wool:** cleaner, smother, whiter and longer

- **Wool grease:** full recovery

- **Wool dust:** previous waste water pollutant becomes a valuable fertilizer

Patent pending

Next steps

Deeper Benchmarking with players on:

Wool, Lanolin and Fertilizer fields

WDS Implementation at industrial level

Partners welcomed to Make it Happen

WDS Life Cycle Assessment

(LEITAT)

Content

- LCA-Introduction
- Goal of the LCA
- Scope of the study
- Life cycle inventory
- Life cycle Impact Assessment
- Benefits of the WDS technology

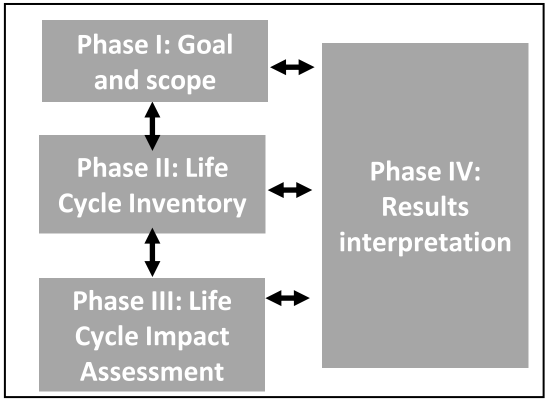
The methodology to assess the environmental performance of WDS technology is the **Life Cycle Assessment methodology** (LCA).

*"The **Life Cycle Assessment** is a tool to analyze the environmental aspects of a product, process or activity throughout its life cycle, considering all inputs and outputs related to every stage analyzed"*

❑The environmental analysis evaluates the environmental behavior of the WDS pilot plant and quantifies the environmental impact generated by the implementation of WDS technology.

❑LCA methodology is based on:

- Standard ISO 14.040: 2006
- Standard ISO 14.044: 2006
- The International Reference Life Cycle Data System (ILCD)
- Four interrelated stages are followed to apply LCA methodology



❑LCA will allow:

- Comparison between two scenarios: conventional vs. WDS processes.
- Quantification of the environmental impacts.
- Specific results will be expressed by the impact categories selected (i.e. climate change,…).

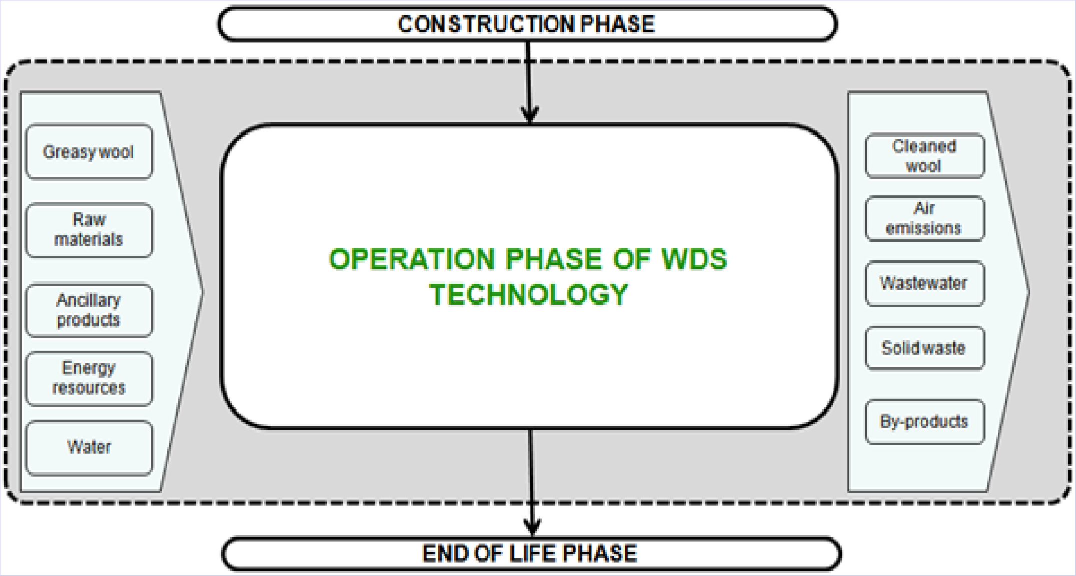
Environmental Assessment

GOALs OF THE LCA:

- To **quantify the potential environmental impacts of WDS technology** in order to identify the hotspots of the technology
- To quantify the environmental benefits of WDS technology in comparison to the current wool scouring process

Environmental Assessment

SCOPE OF THE STUDY:



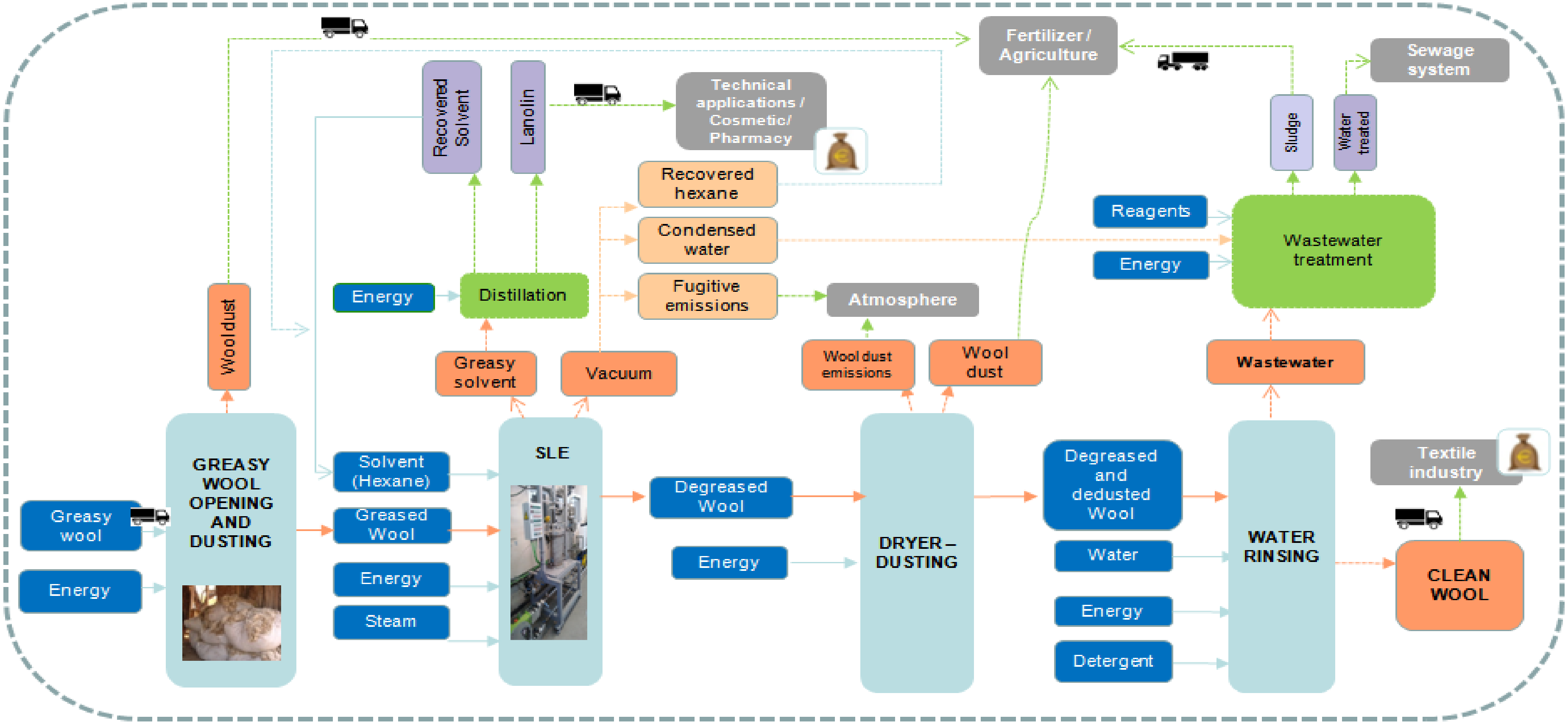
System boundaries

THE FUNCTION:
is to obtain valuable clean wool and grease of better quality while saving water and energy, and reducing waste production.

FUNCTIONAL UNIT:
"to clean 500 kg of greasy Merino Wool Type II (23-24 microns)"

Environmental Assessment

SCOPE OF THE STUDY - Operation phase – WOOL DRY SCOURING PROCESS



LIFE CYCLE INVENTORY (LCI)

For each life cycle stage, **quantitative data (inputs and outputs of the process)** is collected. They are considered in relation to the functional unit.

TAVARES and RMT (project partners) provide the information for the Life Cycle Inventory (LCI) of each life cycle stage considered in the LCA of the current wool scouring and WDS pilot plant. **From experimental results !!!**

Sub-system considered:

- **OPERATION PHASE (energy and water consumption, detergent consumption, wastewater, air emissions, solid waste, by–products, transport)**

Primary data sources	Data are provided by TAVARES & RMT.
Secondary data sources	LCI databases (ECOINVNET 3) and literature.

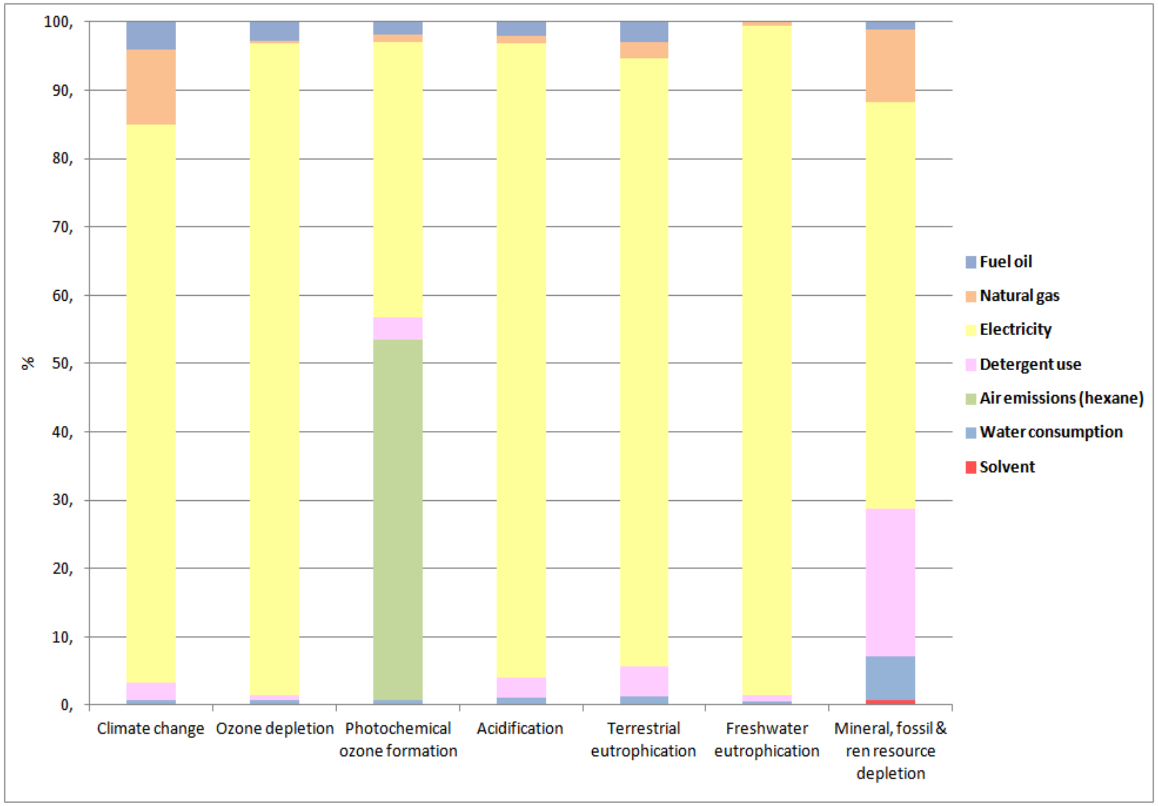
Life Cycle Impact Assessment (LCiA) of Operation phase –WDS process

The potential environmental impacts have been expressed by the following impact categories:

Impact categories selected	Units
Global Warming potential (GWP)	kg CO_2 eq
Ozone depletion	kg CFC-11 eq
Photochemical oxidant formation	kg NMVOC eq
Acidification	molc H+ eq
Terrestrial Eutrophication	molc N eq
Freshwater Eutrophication	kg P eq
Mineral, fossil & renewable resource depletion	kg Sb eq

Environmental Assessment

Life Cycle Impact Assessment (LCiA) of Operation phase –WDS process



Potential environmental impacts of the general WDS process

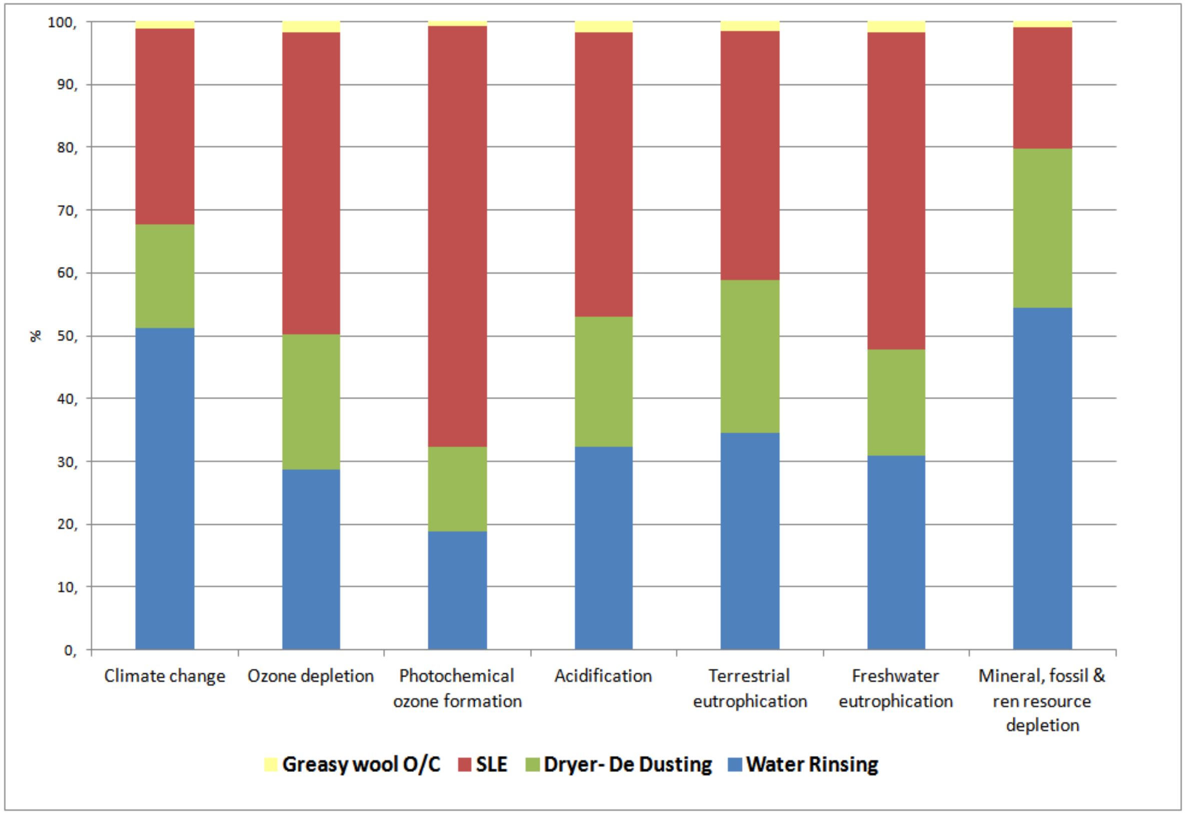
The **main contribution to the environmental impacts** of WDS technology is due to **the energy consumption** (electricity).

✓**Freshwater eutrophication** is the impact category which records the highest impact contribution due to **electricity consumption (98%)**

✓The **air emissions of hexane have an environmental contribution on photochemical ozone formation** (52%)

Environmental Assessment

Life Cycle Impact Assessment (LCiA) of Operation phase –WDS process

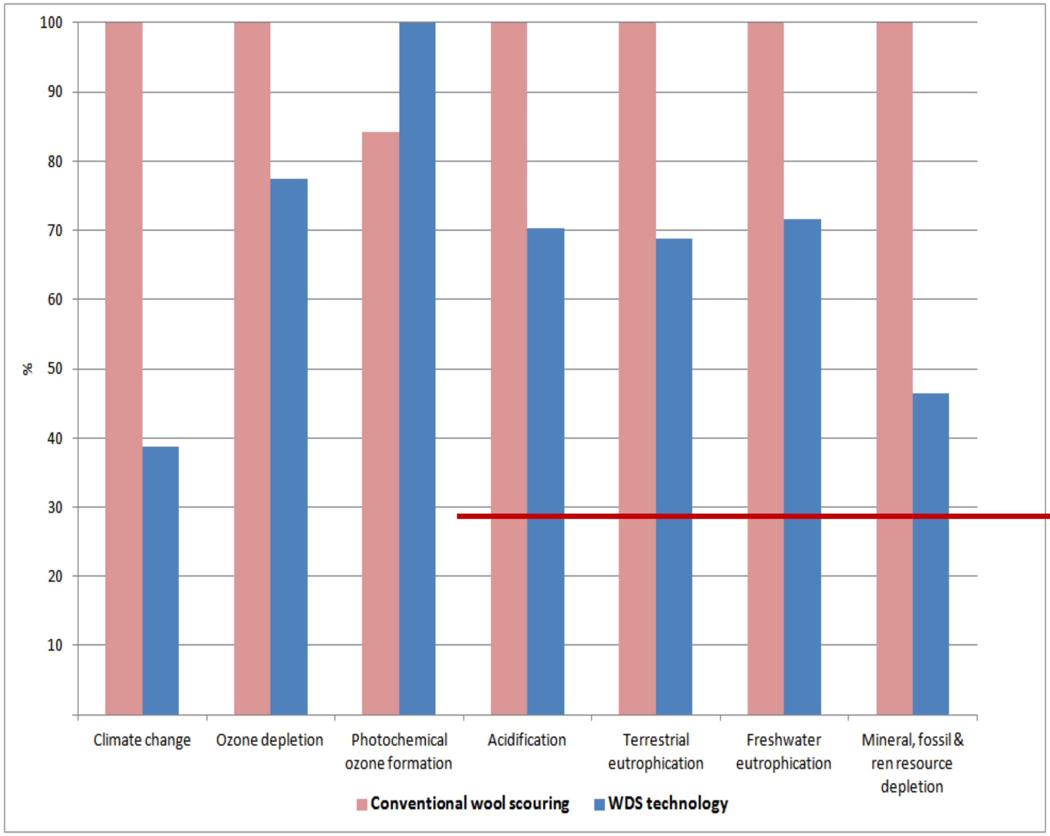


Potential environmental impacts of the WDS sub phases

- The **Solid Liquid Extraction (SLE) and the Water rinsing** are the sub phases with the **major environmental impact contributions** in almost all the impact categories.
(The more intense process takes place during these two sub phases so the demand of water and energy required for them is higher here than in other sub phases described).

- **The greasy wool O/C and dryer and de-dusting** sub phases have a **low environmental impact contribution**.

Comparative assessment between the current process and WDS technology



Comparative processes considered in the operation phase. *Unit:%*

The **current wool scouring process has a higher environmental impact than the WDS technology** in almost all impact categories.!

For the **photochemical ozone formation** category, **the WDS process shows a higher impact than the current process**, which is due to the solvent consumption of hexane necessary to clean the wool.
(3% fugitive emissions of hexane during the wool scouring process at the pilot plant)

The mechanization and automation of the process at industrial level will be reduced these fugitive emissions up to 1%!!!

Environmental Assessment

BENEFITS OF WDS TECHNOLOGY

WHAT IS A CARBON FOOTPRINT ?

➢ The total amount of greenhouse gases produced to directly and indirectly support human activities, usually expressed in equivalent tons of carbon dioxide (CO_2).

In other words: When you drive a car, the engine burns fuel which creates a certain amount of CO_2, depending on its fuel consumption and the driving distance. (CO_2 is the chemical symbol for carbon dioxide). When you heat your house with oil, gas or coal, then you also generate CO_2…

"The carbon footprint is being reduced ***96 kg of CO_2 eq***. per functional unit by WDS technology."

CONCLUSION

The LCA analysis demonstrates that WDS technology has been developed as an **innovative** and **eco-friendly** wool scouring process.

WDS Conclusions

(LEITAT)

Conclusions

The Wool Drying Technology (WDS) has demonstrated :

✓WDS enhances **Wool Quality:**
Whiter, cleaner, smoother, fibre entanglement free,
higher combing yield and lower grease content

✓WDS **recovers**:
95% **Wool Grease** content (vs 40% in conventional wool scouring)
~ 100% **Wool Dust** (100% when implementing rising water evaporators)

Conclusions

✓**Technical viability**: Demonstrated

✓**Economic viability**: Assured vs Water scouring

✓**Minimum environmental impact**:

Reduction:

✓>75% COD in rinsing water

✓75-100% Detergent and chemicals consumption

✓75% Water consumption / Wastewater

⇨ 100% reduction when implementing rising water evaporators

⇩

Zero waste generation !!!

Conclusions

-Wool Dry Scouring friendly process focuses on a wide range of **potential target markets**

-Associations for sheep farming
-Wool scouring companies
-Wool manufacturers and designers
-Wool textile federations
-Fertilizers manufacturers
-Lanolin manufacturers
-European engineering companies
-Wool research centres and the European scientific community
-Waste managers consultants
-Public bodies

-WDS can **enhance the competitiveness of the wool secto**r thanks to

✓selling byproducts (wool wax and wool dust)

✓decreasing of manufacture costs (reduction of water, energy, chemicals consumption, wastewater treatments and land disposal)

THANKS FOR YOUR ATTENTION

Barcelona, 4 February 2016

Eco-Efficient Dry Wool
Scouring with total by-products recovery
(LIFE11 ENV/ES/588)

With the contribution of the LIFE financial instrument of the European Union