ADVANCES IN
HYDROTHERMAL CONVERSION OF INDUSTRIAL BIOGENIC RESIDUES INTO INTERMEDIATE BIOENERGY CARRIERS

RESULTS FROM THE **F-CUBED PROJECT**

F-CUBED

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 884226.

Pilot scale hydrothermal treatment of paper sludge, olive pomace and orange peels into intermediate energy carriers

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TNO

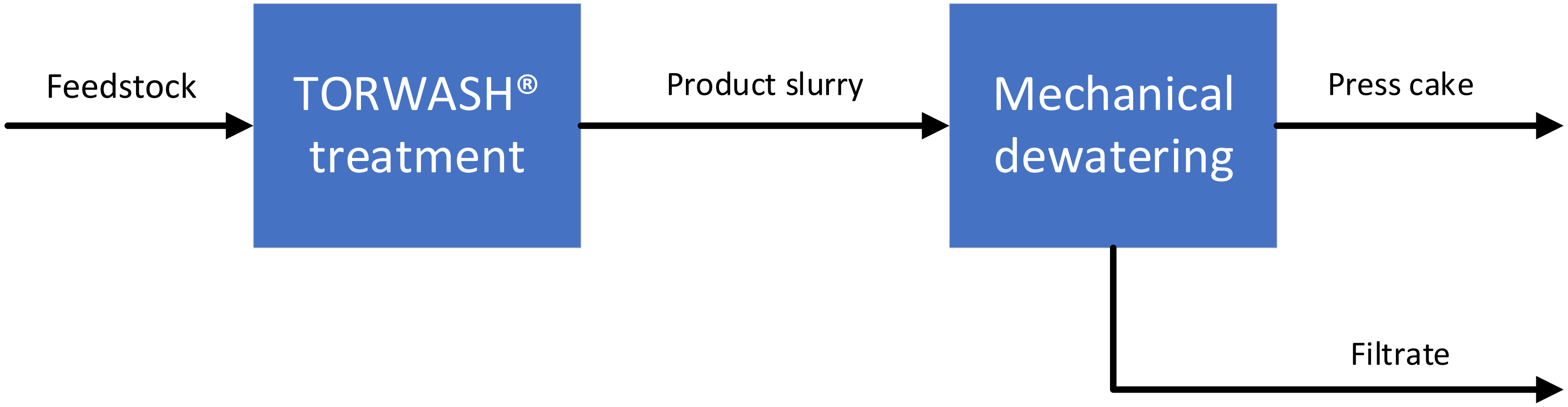
About TNO

- Independent Research institute
- Almost 4000 employees
- Research aimed at maximum impact on big socially relevant topics
- Topics range from energy to health and defence to lifestyle

Biobased circular Technologies

- Part of Energy and Material Transition cluster
- Focus on developing technologies for biomass upgrading from lab-scale towards the market

Focus of this talk



Development from a lab-scale batch process to continuous pilot scale

Hydrothermal treatment

Hydrothermal carbonization vs Torrefaction

Main difference: Water

Hydrothermal carbonization

Wet streams can be applied
Thermal decomposition (hydrolysis)
Removal of minerals and salts

Torrefaction

Lower operational pressure
Mature technology

Upgrading of challenging feedstocks

- Feedstocks with too much water and/or too much salt

How to make these streams valuable

- To produce valuable (fuel) products

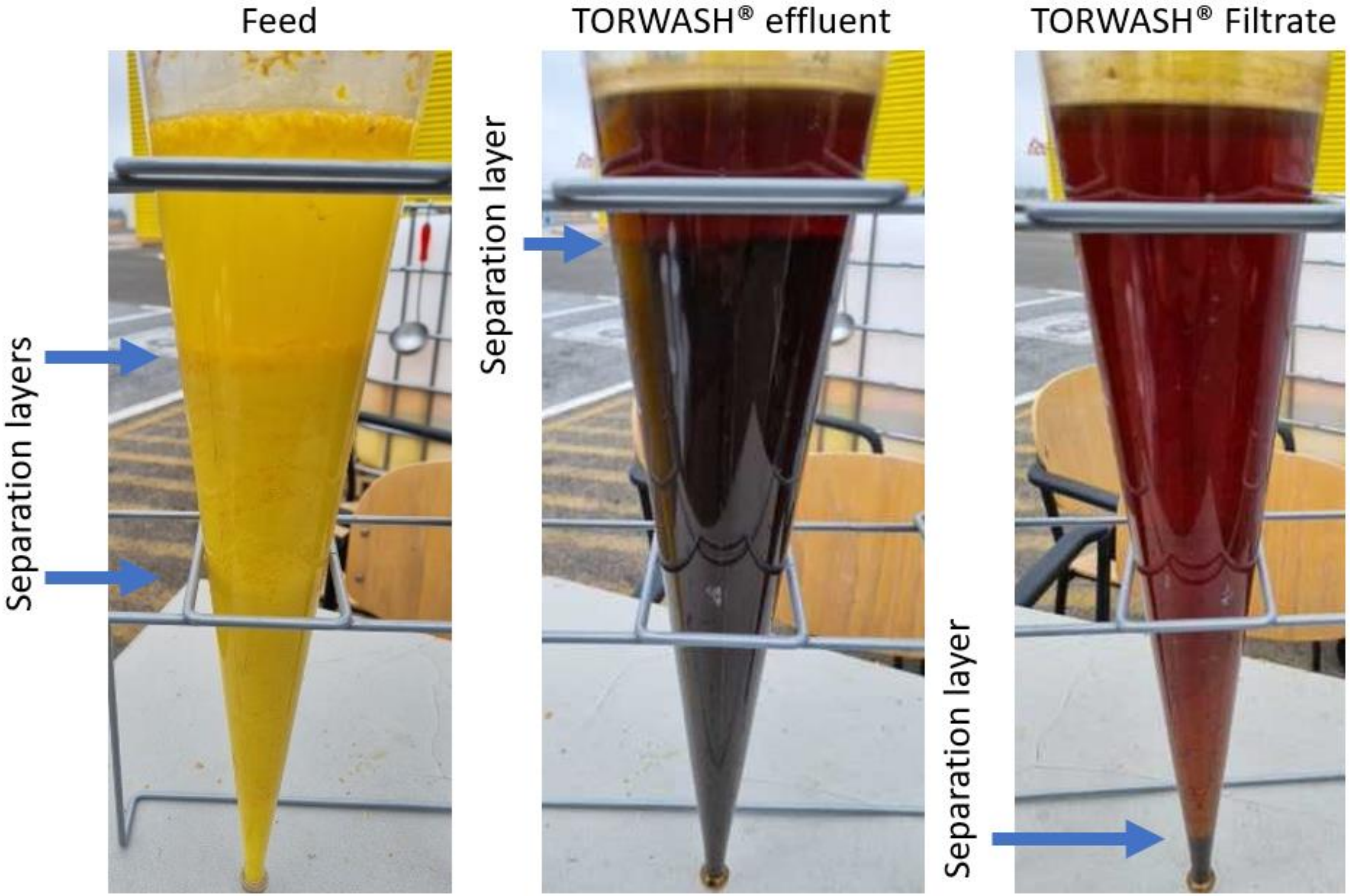
- To co-recover valuable by-products

Orange peels

Paper sludge

Olive pomace

What happens?

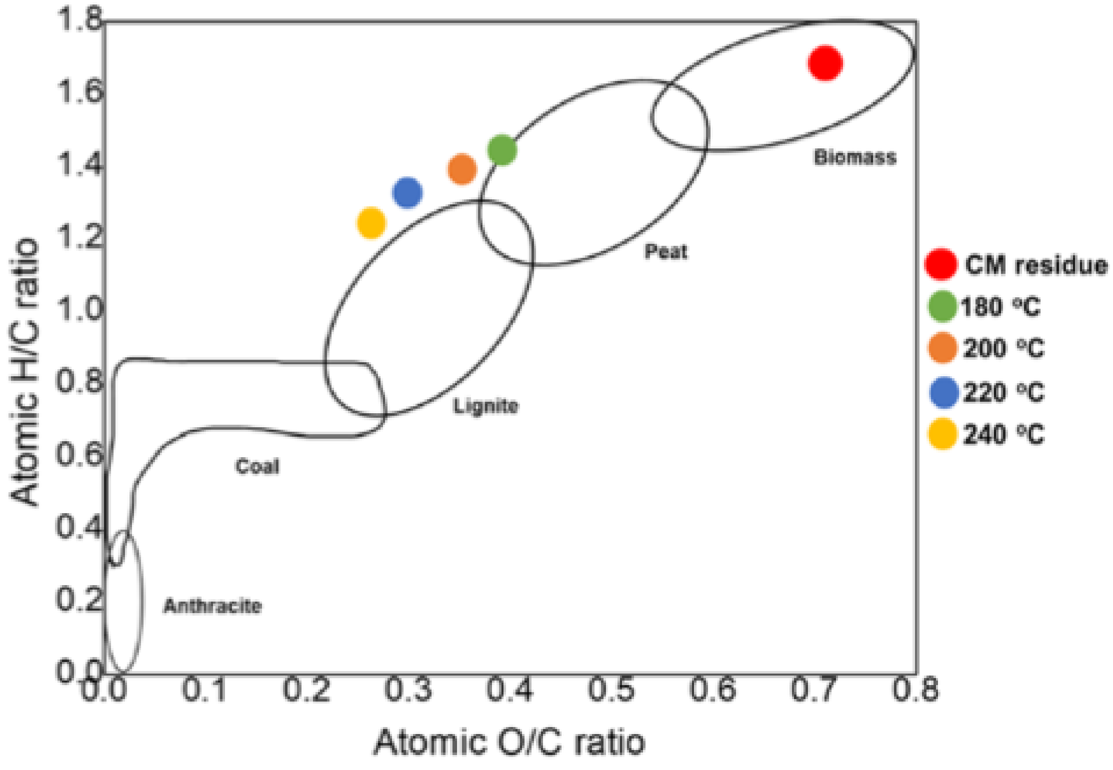


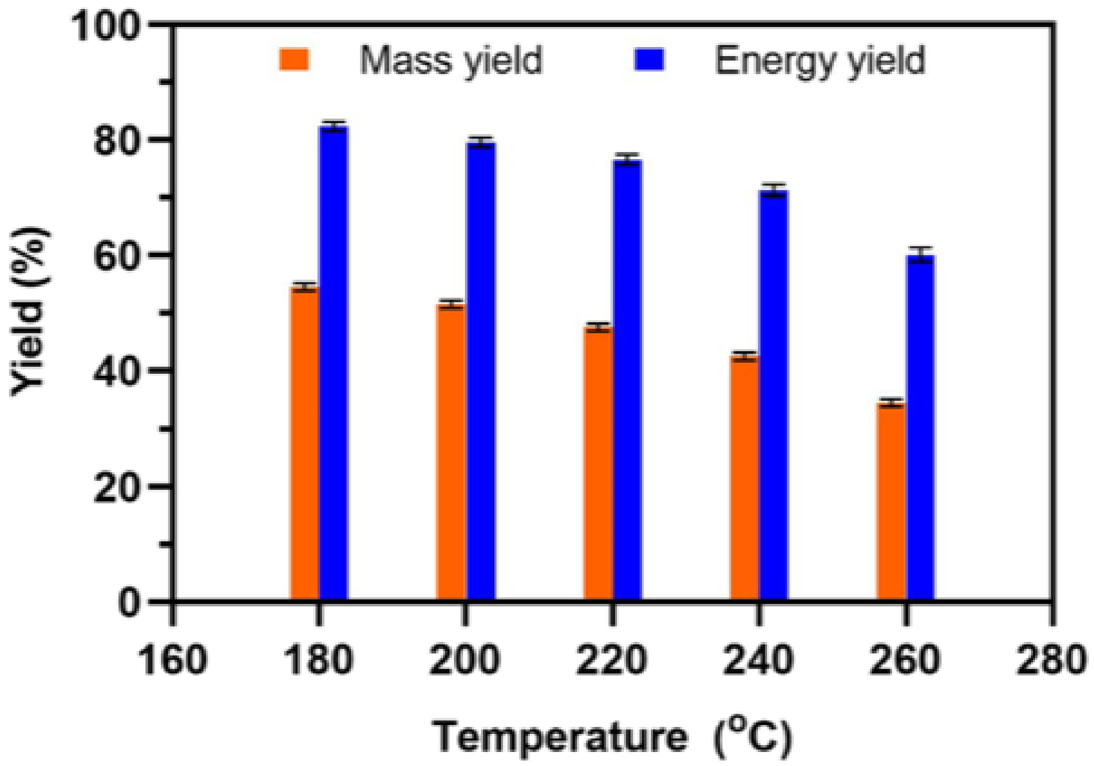
What happens?

Feed (1.5 – 1.8% d.m.)

Filter cake (40% d.m. average)

Main challenge: Optimal temperature





Source: Tsarpali et al. Valorization of Brassica carinata biomass through conversion to hydrolysate and hydrochar. Biomass conversion and biorefinery **2022**

Main challenge: Optimal temperature

Dewaterability:

Biomass becomes more brittle, making the product easier to compress

Too low temperature → not dewaterable

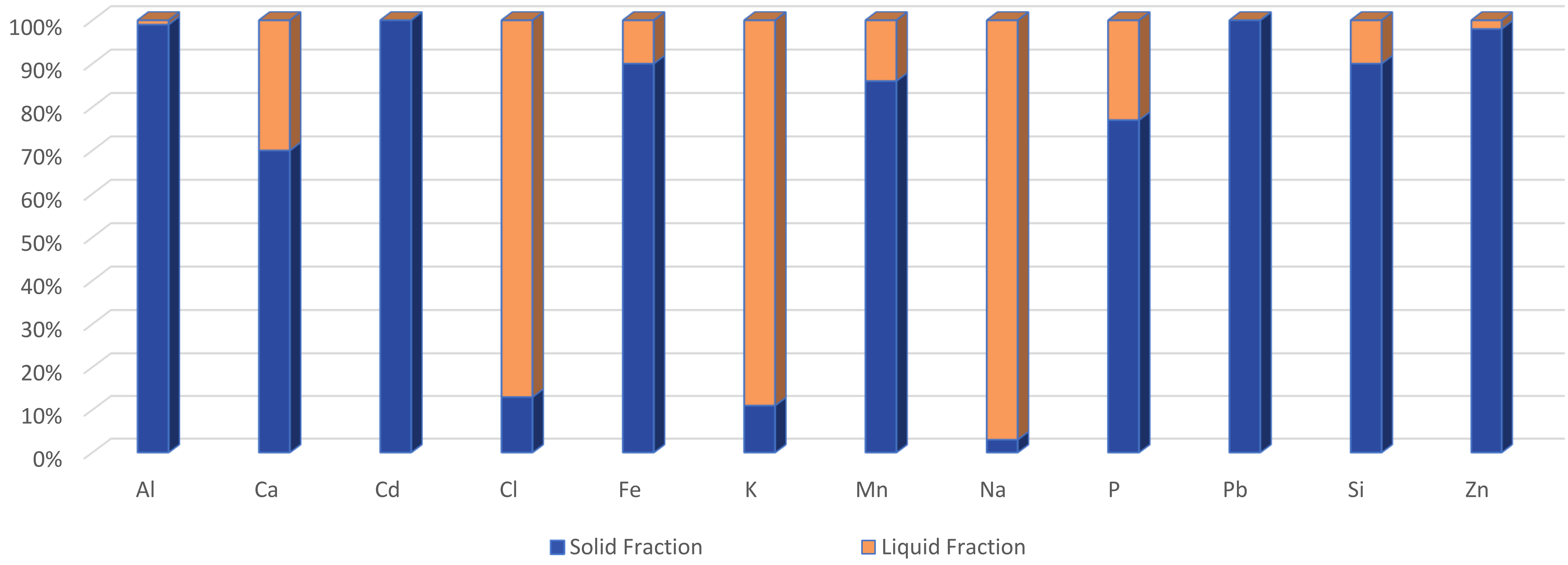
Digestability:

Organic fraction partially dissolves in the aqueous phase

Too low temperature → low dissolved fraction
Too high temperature → phytotoxic components produced

Partitioning of key elements

- Sodium, potassium and chlorine partition mainly to the liquid fraction
- Most metals partition mainly to the solid fraction



Lab-scale preparations

Enabling pilot testing

Goals

- Determine chemical and physical properties of the wet organic streams
- Determine optimal process conditions
- De-risk pilot plant campaigns


Orange peels


Paper sludge


Olive pomace


1. Multiclave set-up (6 x 125 mL): To determine the optimal conditions in terms of product dewaterability and potential for value-added products (e.g. oils, nutrients)


2. Autoclave set-up (20 L): To determine the mass balances

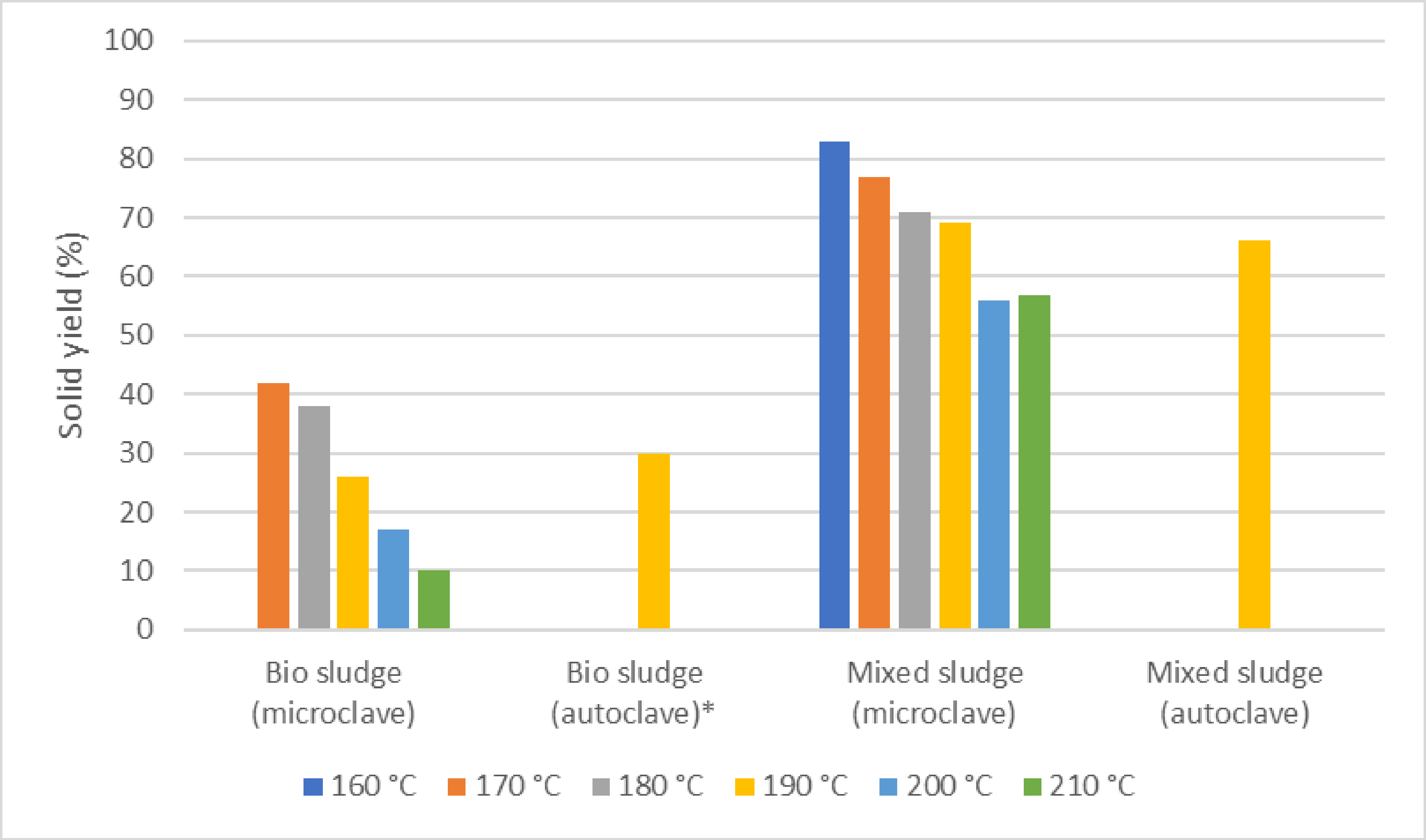

3. Pilot installation (25 kg/h): To produce larger amounts of product and validate the lab scale results for the proof of concept on larger scale

Filtration/ Pressing

→ Solids → Analysis of dry matter content & chemical analyses

↓ Liquid effluent ↓ Sample for anaerobic digestion testing

Results of lab testing



Initial pilot testing

Sludge Type	TORWASH® Temperature (°C)	Dewaterability (% d.s. in pressed cake)
Autoclave Tests		
Bio-sludge	190	61
Mixed sludge	190	61
Pilot tests		
Bio-sludge	185	not pressable
Bio-sludge	195	48
Bio-sludge	200	49
Mixed sludge	185	34
Mixed sludge	195	61
Mixed sludge	205	63

Pilot campaign

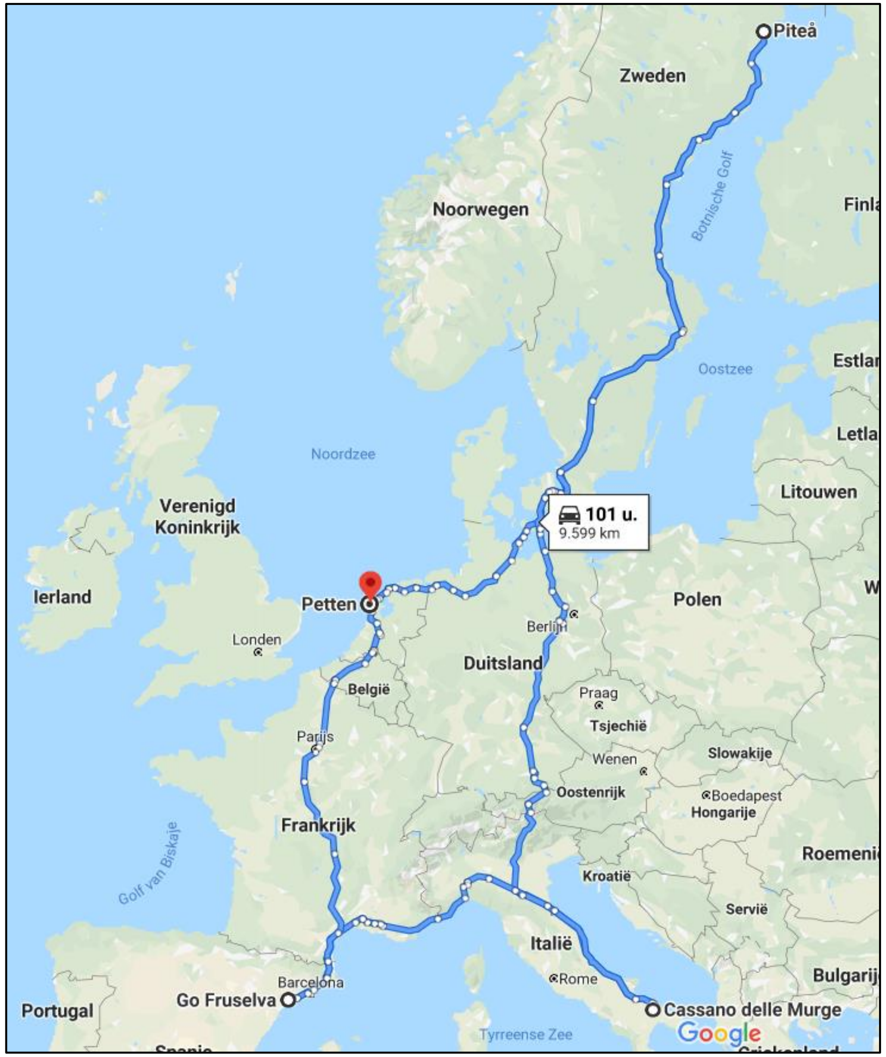
Enabling pilot testing

Goals

- Pilot tests on location where the residue streams are generated
- Move TORWASH technology from TRL 3 to TRL 5
- Proof of concept for feedstock flexibility and bio-energy carrier production
- WP goals for operational hours and press cake production

European tour

Smurfit Kappa paper factory, Piteå, Sweden	 
I.V.O.M. S.r.l. olive oil mill, Bari, Italy	
Tarragona, Catalonia, Spain	 



TORWASH on site

Pilot campaigns

Feedstock	Operational time	Dry press cake production	Main issue
Bio sludge	410 hours	54 kg	Very low dry matter content of feedstock
Olive Pomace	336 hours	192 kg	Presence of olive stone
Orange Peel	472 hours	117 kg	Low percentage of solids in the feed to hydrochar

Effect of F-CUBED process

Dry matter content (%)	↑
Ash content (550 °C, % db)	↓
C (% db)	↑
N (% db)	-
H (% db)	-
O (% db)	↓
Higher heating value (MJ/kg db)	↑

Effect of F-CUBED process

	Paper Sludge		Olive Pomace		Orange Peels	
	Feed	**TORWASH press cake**	**Feed**	**TORWASH press cake**	**Feed**	**TORWASH press cake**
Dry matter content (%)	1.6	42	22	58	22	42
Ash content (550 °C, % db)	19.7	24.9	9.5	1.7	5.8	3.2
C (% db)	41.3	46.0	53.3	63.8	47.0	56.3
N (% db)	6.3	4.5	1.3	1.5	2.1	2.2
H (% db)	5.8	5.8	6.8	8.3	6.1	6.3
O (% db)	32.7	22.2	33.4	24.3	42.5	32.1
Higher heating value (MJ/kg db)	18.1	20.8	23.0	29.2	18.4	22.1

All results as expected, except from the TORWASHed paper sludge ash content

Effect of F-CUBED process

	Paper Sludge		Olive Pomace		Orange Peels	
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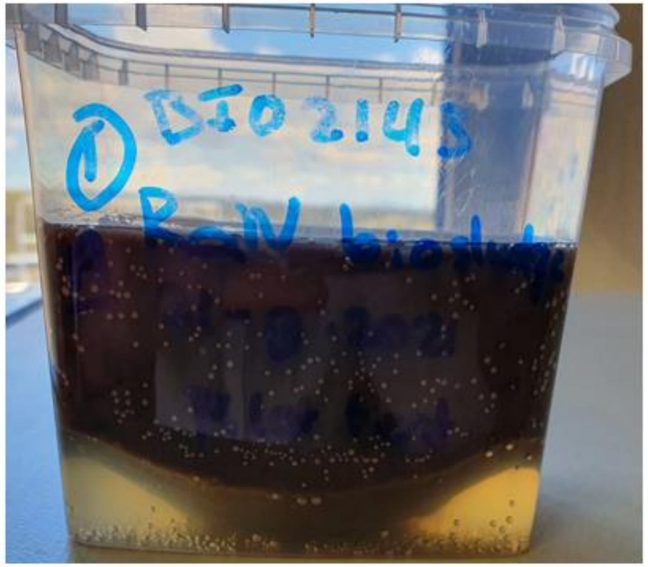
H (% db)	5.8	5.8	6.8	8.3	6.1	6.3
O (% db)	32.7	22.2	33.4	24.3	42.5	32.1
Higher heating value (MJ/kg db)	18.1	20.8	23.0	29.2	18.4	22.1
TORWASH efficiency						
Total solid yield (%)	39		46		33	
Volume reduction (%)	98.7		83.0		85.6	
Moisture removal (%)	99.2		90.9		89.7	

- Total solid yield is relatively low for all solids
- High volume reduction and moisture removal




Chamber 1


Chamber 4

THANK YOU

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