F-CUBED

The F-CUBED project: Hydrothermal conversion of wet organic residues to fuel pellets

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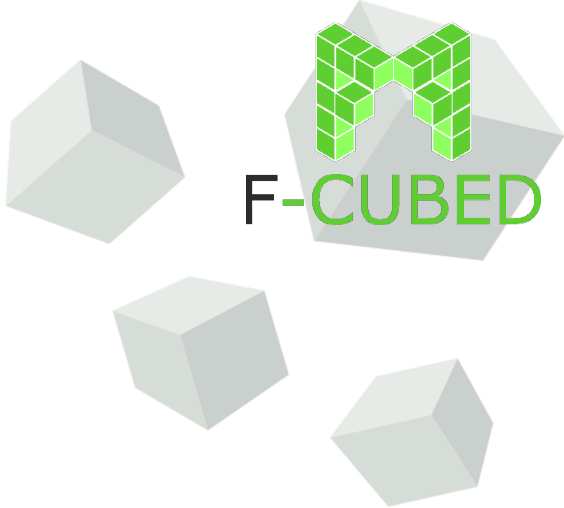
Contents

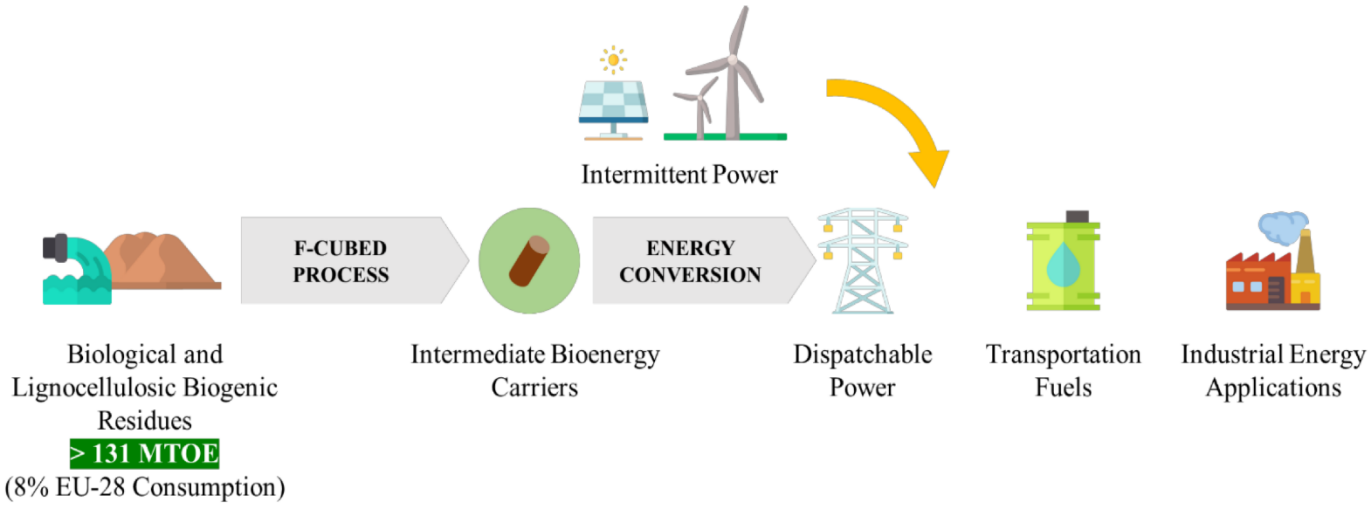
- Introduction
  - The F-CUBED Concept & Project
  - The TORWASH® Process
  - The F-CUBED process
- Cases: paper sludge, olive pomace, orange peels
- Experimental results
- Conclusions & Next steps



1 Introduction

F-CUBED Concept & Objectives

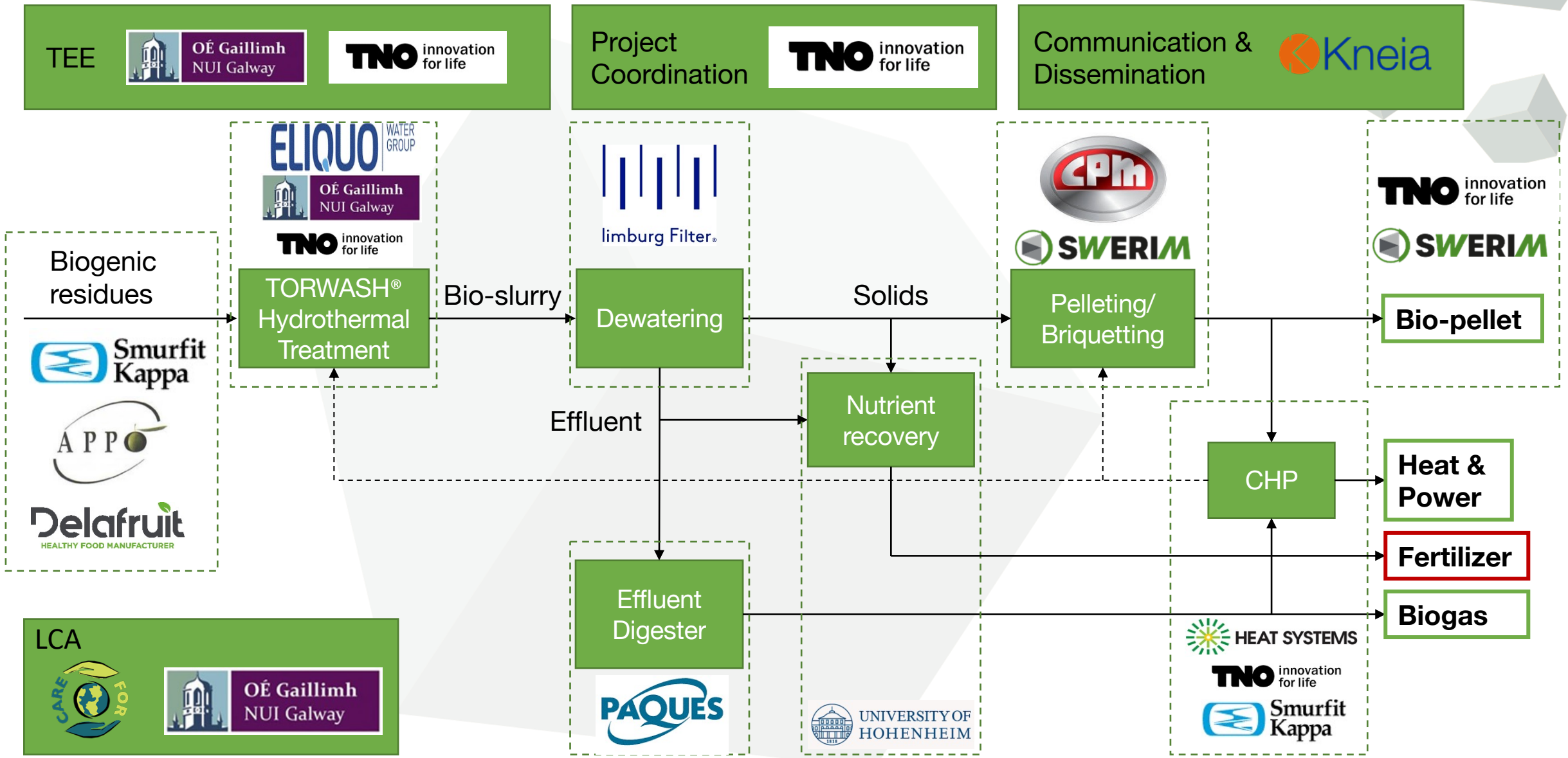
Hydrothermal conversion (TORWASH® process) of low quality biogenic residues into intermediate bioenergy carriers, increasing the flexibility of a renewable energy system.



OBJECTIVES

- Apply continuous hydrothermal and dewatering pilots in three industrial sites to prove the concept → paper sludge, olive pomace and fruit & vegetable waste
- Increase the energy density of biogenic residues
- Demonstrate improvement in residue handling costs and reduction of GHG emissions
- Validate parallel recovery of value-added products

The F-CUBED Concept & Project



The TORWASH® Process

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Heat

+

Washing

=

TORWASH®

→ **150-250°C**

+

→ **Pressurized water**

=

→ **Exposed salts**
Brittle biomass
Compressible fibers
Dissolved organics

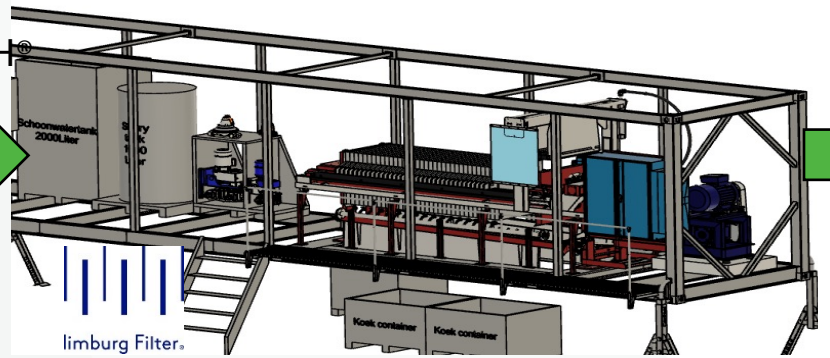
The F-CUBED process

Wet biogenic residue

TORWASH® pilot plant

TORWASH® product

Membrane filter press pilot



Pressed solid cakes

Pellets

WP1. Enabling pilot testing

- Optimisation of conditions

WP2, WP3, WP4 - Pilot campaigns on location

- Where residues are generated at industrial sites
- Move TORWASH® technology from TRL 3 to TRL 5
- Proof of concept for feedstock flexibility and bio-energy carriers production

2 Cases (feedstocks) considered

Paper (bio)-sludge (Smurfit Kappa)

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Different types of paper sludge

- **Biological (bio-sludge)**
  - By-product of the wastewater treatment plant (aerobic/biological treatment) at the paper mill
  - Dry solids content varies from 1 – 4%
  - Difficult to dewater
- **Fibre sludge**
  - By-product of paper production containing solids in the form of short cellulose fibres
  - Easy to dewater
  - Can be re-used on site to make paper
- **Mixed sludge**
  - Mix of bio-sludge (40%) and fibre sludge (60%)
  - Dewatered to a dry matter content of 30 – 35% with polyelectrolyte addition

Olive pomace (CHIMIENTI Mill)

Chimienti Olive Mill location close to the TORWASH field testing «campus». *Source: APPO*

Olives ready to be processed. *Source: CFE*

Olive pomace

Olives processed : $90*10^3$ t/y
Capacity: $18*10^3$ kg/h
Olive pomace from the process: $67*10^3$ t/y

Fruit & Vegetable Residue (Delafruit)

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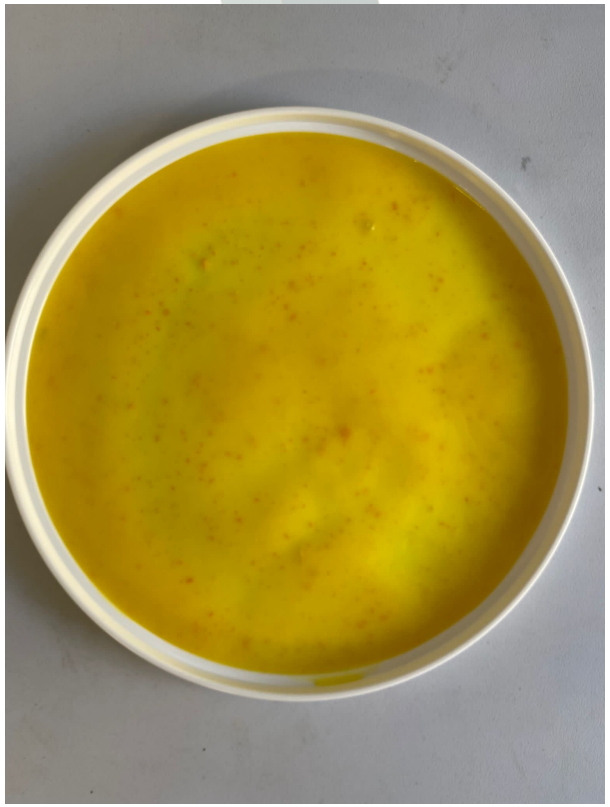
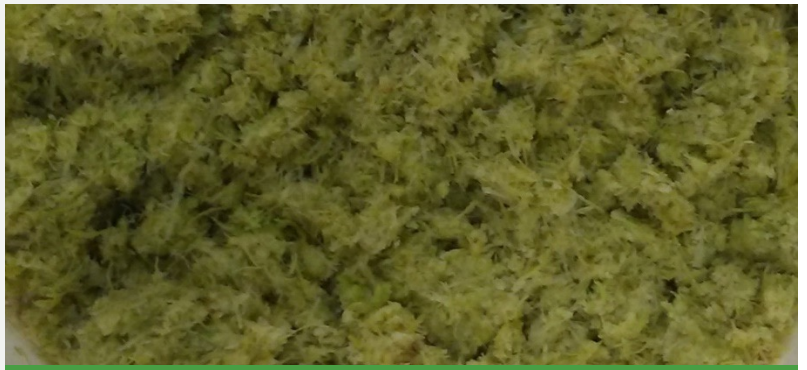
CITRUS PLANT RAW MATERIAL

CITRUS PLANT WASTE



COLD PRESS VEGETABLE RAW



COLD PRESS VEGETABLE WASTE

Pilot-scale equipment

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3 Results (so far…)

Preliminary testing

Paper sludge

Olive pomace

Orange peels

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

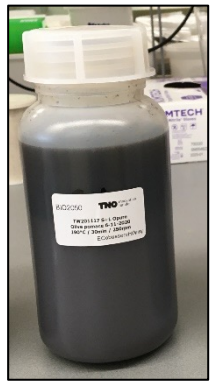
Filtration/ Pressing

Solids

Analysis of dry matter content & chemical analyses

Liquid effluent

Sample for anaerobic digestion testing



Biological paper sludge

- On-site testing in July 2021
- Over 400 hours of operation
- Low solids content in feed (1.5 – 1.8% d.s.)
- Filter cakes produced with approx. 40% dry solids
- No use of dewatering aids

- **Volume reduction of 99% of residue**
- **Solids upgrading**
  - 13% higher energy density
  - 85% lower Cl
  - 79% lower K
- **Biogas production from filtrate fraction**
  - Anaerobic biodegradability 62 %
  - Biogas potential 3.2 Nm^3 CH_4/m^3 effluent

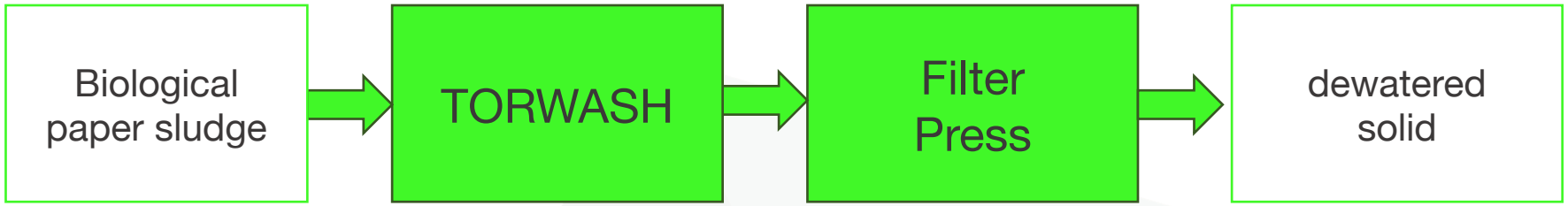
On-site testing at Smurfit Kappa in Sweden

Solids Use

- Pellets (solid fuel)
  - Pellet durability >96%
  - Combustion testing in June 2022

- Use in steelmaking
  - Blended with anthracite for use in blast furnace injection process
  - Blend of 30% bio-sludge solids with anthracite was the most promising (in terms of safety and combustion efficiency)
  - P content is a limiting factor
  - Briquettes of bio-sludge solids with iron powder had high strength and density and are suitable for use in electric arc furnace charging

Potential of nutrient recovery



Solids are rich in phosphates

86% extraction with oxalic acid

91% recovered by precipitation

41% pure phosphate

Olive pomace

- On-site testing in October 2021
- Over 300 hours of operation
- Filter cakes produced with approx. 58% dry solids content
- Olive oil recovered during dewatering (1% of filtrate) – *lampante oil quality*

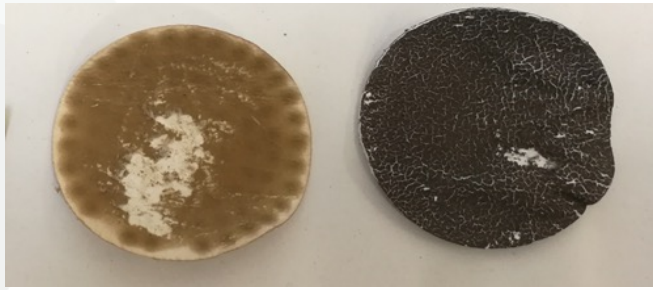
- **Volume reduction of 83% of residue**
- **Solids upgrading**
  - 21% higher energy density
  - 96% lower Cl
  - 95% lower K
- **Biogas production from filtrate fraction**
  - Anaerobic biodegradability 57%
  - Biogas potential 5.7 $Nm^3\ CH_4$ / m^3 effluent

Olive pomace

- Pelleting difficult due to oily nature of the solids
- Pellets are a bit “sticky”
- Combustion tests in June 2022

Nutrient recovery

- Not beneficial from solid fraction
- From liquid fraction, recovery as struvite ($NH_4Mg(PO_4)\cdot 6H_2O$)



Precipitate from liquid fraction separated in the dewatering step

Precipitate from post-digested effluent

Orange peels

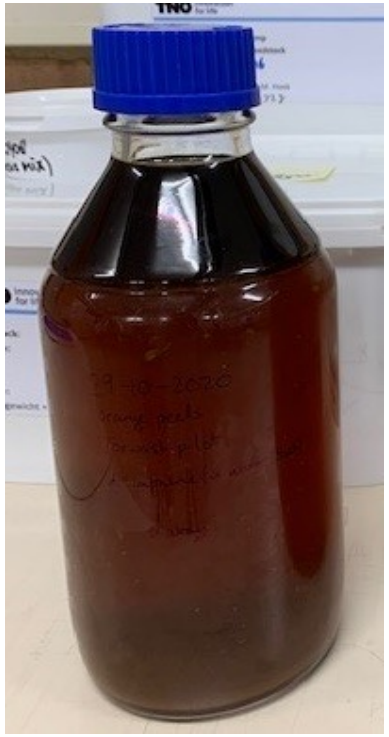
- On-site testing is currently happening
- Solids dewatered to approx. 40% dry matter
- Recovery of d-limonene in the reactor (~38%)

Orange residue: 22% DM

TORWASH Feed: 4-6% DM

Dry Cake: 39% DM

Limonene: 2.3 mL/kg orange residue



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5 Summary & Next Steps

Conclusions

- **The TORWASH® treatment results in:**
  - Efficient dewaterability with DM 40 % for paper sludge and orange peels & 60% for olive pomace
  - No need for dewatering aids
  - Removal of K and Cl from solids
  - Biodegradable liquid fraction

- **Potential for creating added-value by:**
  - Recovering P and N from solids (especially paper sludge)
  - Use of (paper sludge) solids in steelmaking to replace coal
  - Recovering oils (limonene, olive oil) during the process

- **Optimization opportunities:**
  - Pre-thicken / concentrate low solids feeds
  - Optimize the filter press operation to improve dewaterability

Next Steps

- **Combustion testing**
  - Evaluate the fuel quality of pellets produced from the three feedstocks
- **Economic and Environmental Impact**
  - LCA and TEE – comparing reference cases to the F-CUBED cases
  - Models (process model, reactor model, supply chain model)
- **Other ideas**
  - Scale-up opportunities
  - Different types of residues or feedstocks or blends
  - Other uses for solid/liquid fraction

Thank you!

Any questions?

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