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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.

Process modeling and system design

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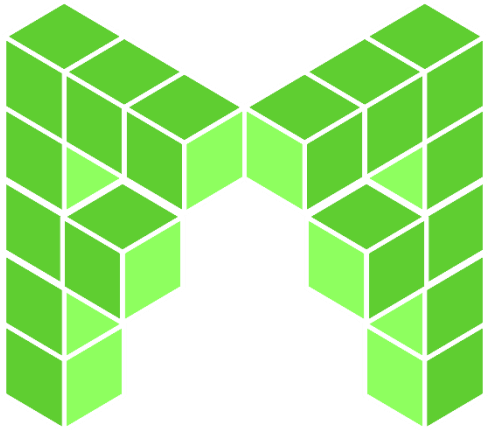

F-CUBED

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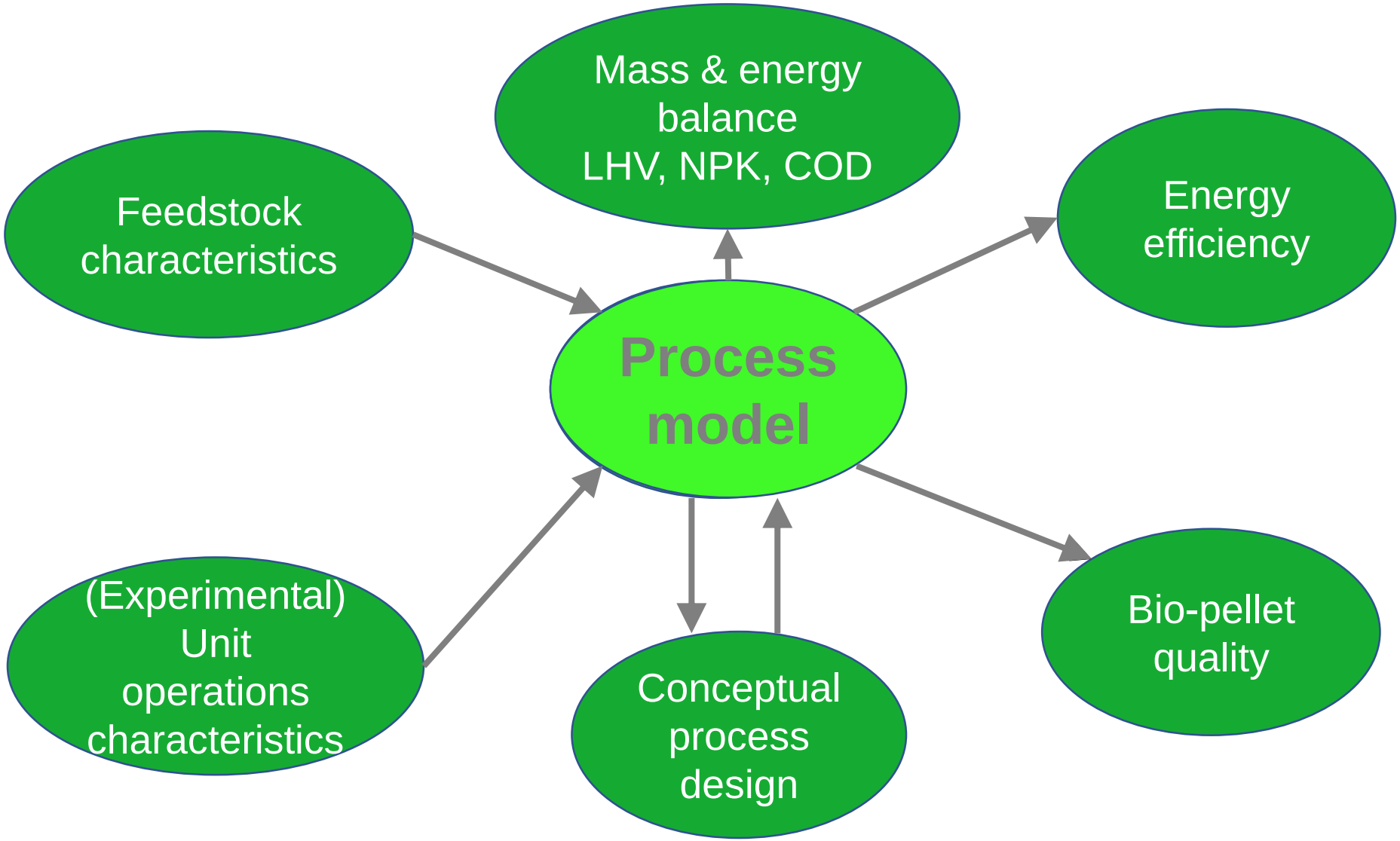
Florence, Italy/Online

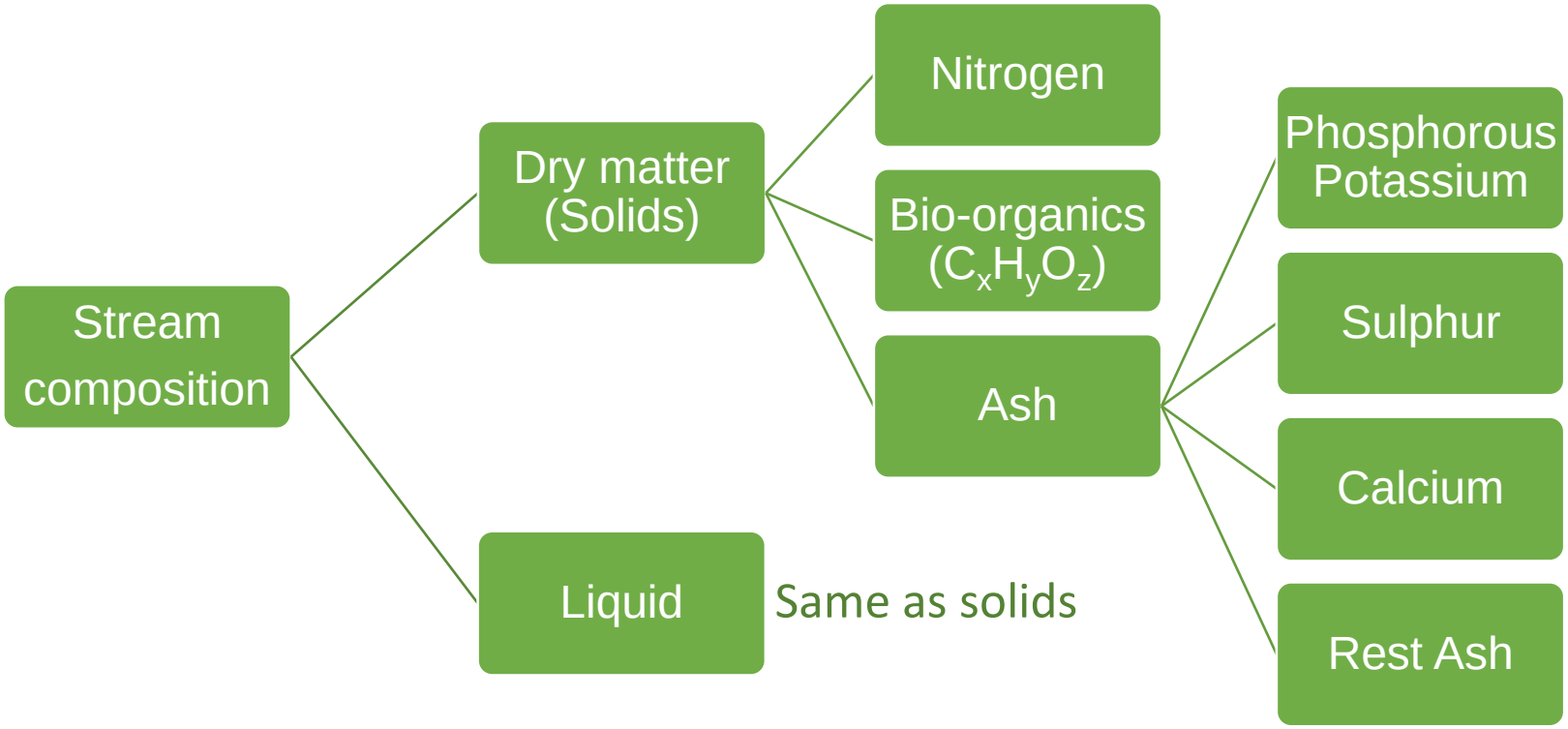
Introduction



Approaches to modelling

#	Model type	Advantages
1	Spreadsheet models	Customisation
2	Flow sheeting Biorefinery-type models *(lignin, glucan, xylan, etc)*	Process steps integration Predictive value
3	Flow sheeting Thermal conversion type models *(C,H,O, ash etc)*	Process steps integration Alignment with experimental data

Modelling approach



Stream composition definition using pseudo-components: e.g. Ca = $CaCO_3$

Key unit operations

- **TORWASH unit**

a Bio-organics + b S → c Upgraded bio-organics + d CO_2 + e H_2O + f H_2S

a CxHyOz + b S → c Cx'Hy'Oz' + d' CO_2 + e' H_2O + f' H_2S

- **Anaerobic digestion:**

Experimental data for anaerobic digestability. Conversion with the Busswell equation:

$$C_nH_aO_bN_cS_d + \left(n - \frac{a}{4} - \frac{b}{2} + 3\frac{c}{4} + \frac{d}{2}\right)H_2O \rightarrow \left(\frac{n}{2} - \frac{a}{8} + \frac{b}{4} + 3\frac{c}{8} + \frac{d}{4}\right)CO_2 + \left(\frac{n}{2} + \frac{a}{8} - \frac{b}{4} - 3\frac{c}{8} - \frac{d}{4}\right)CH_4 + cNH_3 + dH_2S$$

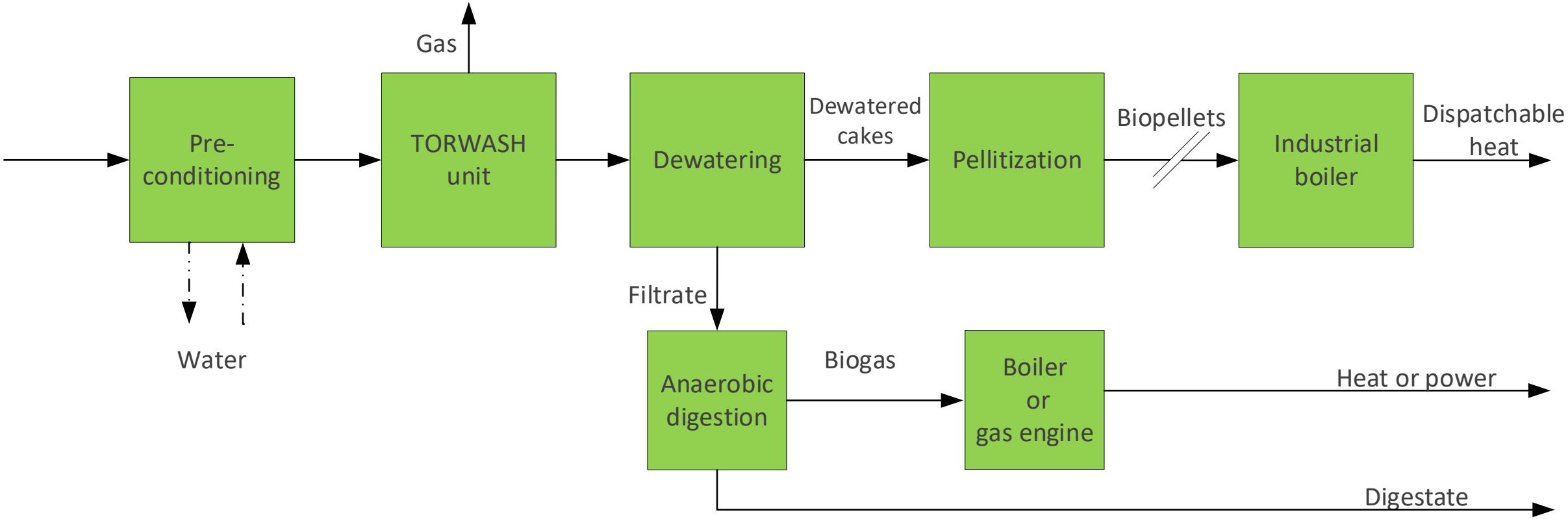
- **Filtration with standard models**

Full separation of solids phase to solids stream

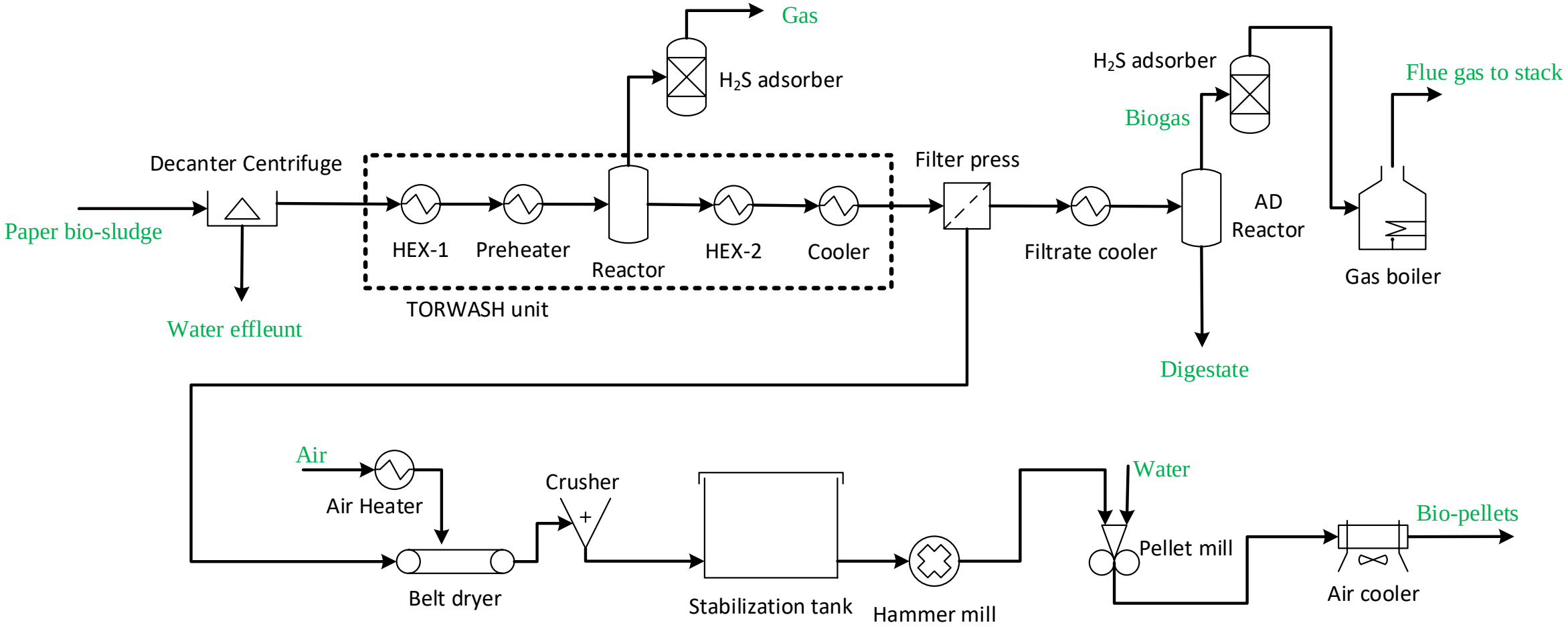
Distribution of liquid phase over the filtrate stream and solids stream

S. Shah, J.W. Dijkstra and H. Wray, Biomass and Bioenergy, submitted 2023

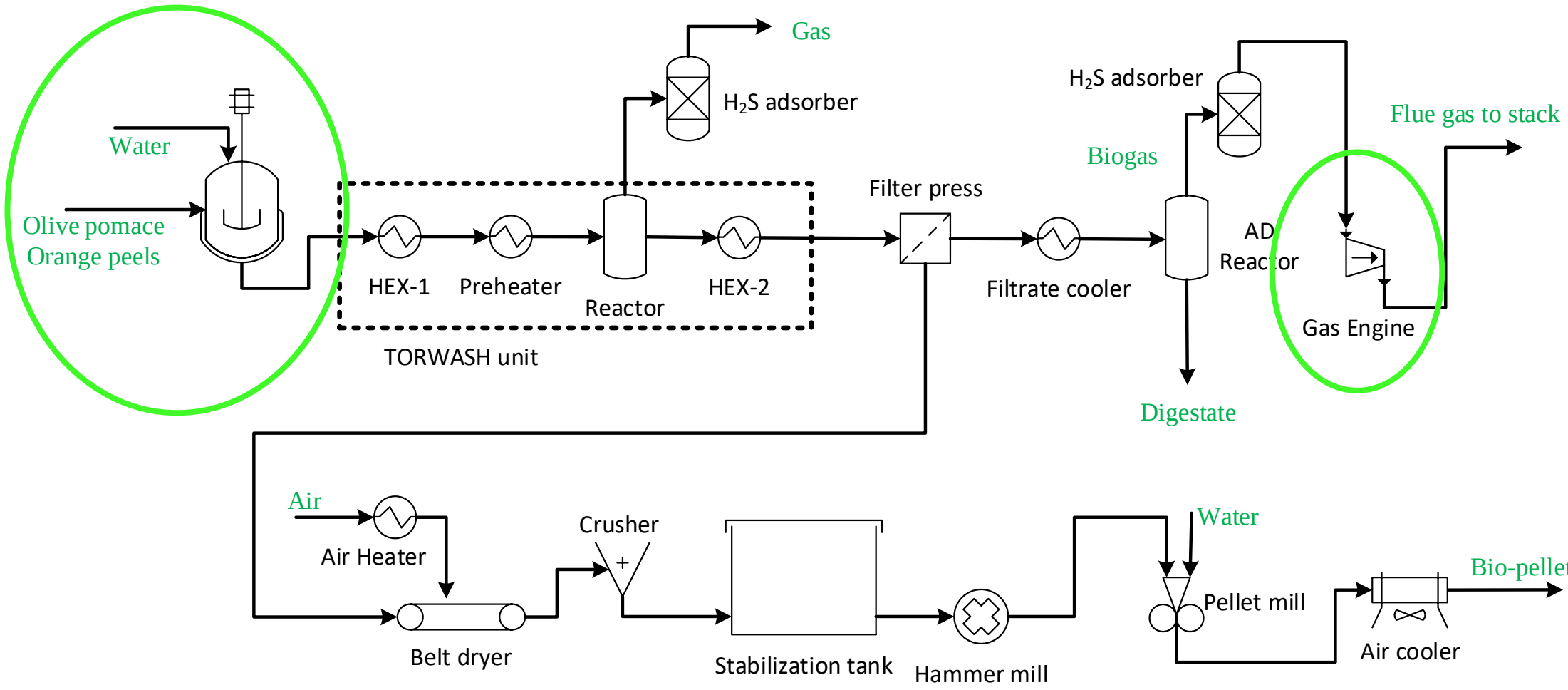
F-CUBED Block scheme



Process flow diagram (PFD) – Paper sludge

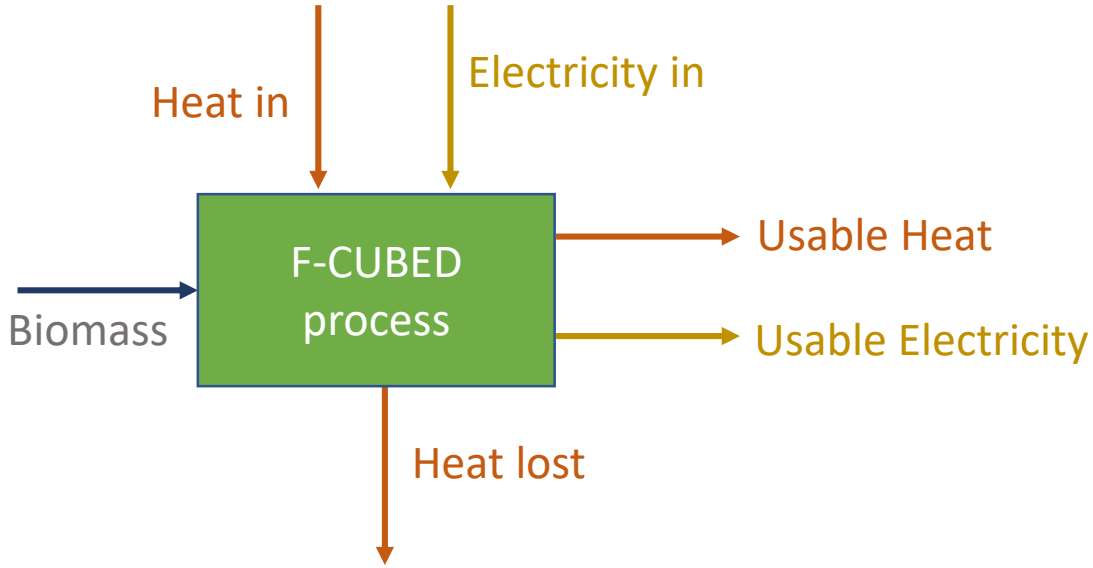


PFD – Olive pomace & Orange peels



Key performance indicators

- Bio-pellet quality → EnPlusB standard
- Energy efficiency
  - Process efficiency (η_p)
    - Energy efficiency towards bio-pellets only
  - Complex efficiency (η_c)
    - All input/output streams
    - Primary energy based



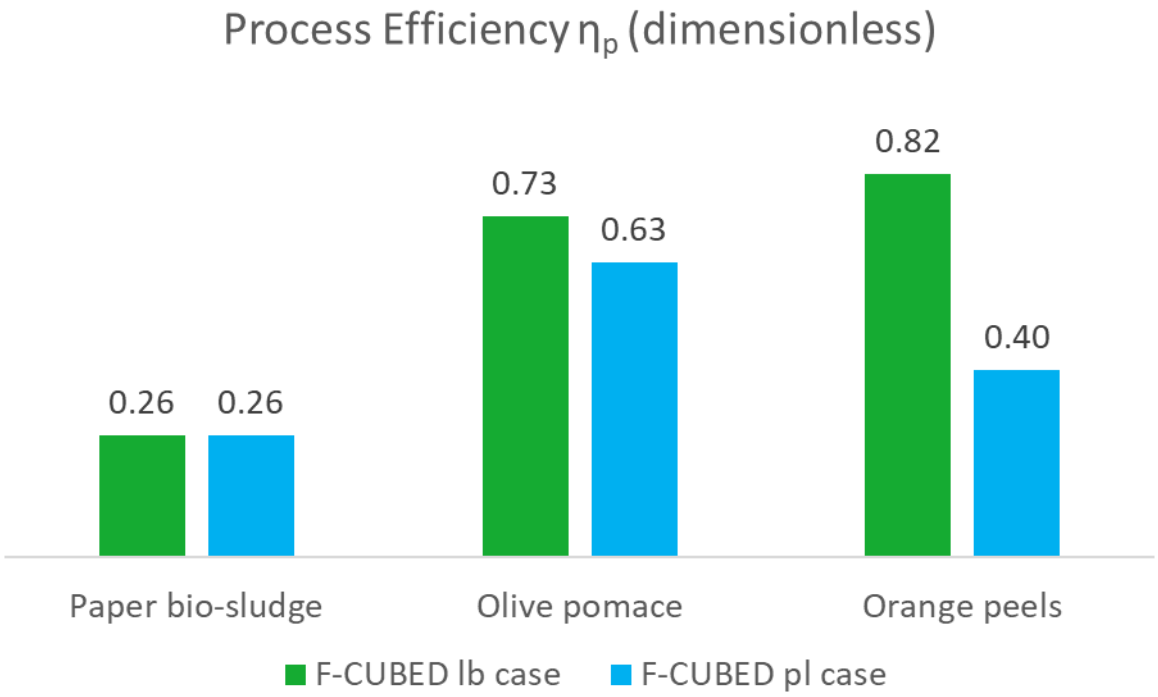
- Scenarios/cases
  - Three feedstocks (paper bio-sludge, olive pomace, orange peels)
  - F-CUBED system, and reference system with anaerobic digestion only (AD)
  - Three cases lab experiments (lb) and pilot experiments (pl), custom case (cstm) with process optimisation

Bio-pellet quality

Parameters	F-CUBED targets	(EN*plus* B)	Paper bio-sludge	Olive pomace	Orange peels
Moisture (wb)	< 10 wt%	≤10 wt%	7 wt%	6 wt%	6 wt%
N (db)	< 2.5 wt%	≤1 wt%	6.8 wt%	2.9 wt%	1.6 wt%
S (db)	< 0.3 wt%	≤0.05 wt%	2.1 wt%	0.2 wt%	0.1 wt%
Ash (db)	N/A	≤2 wt%	41 wt%	1.1 wt%	2.3 wt%
LHV	> 10 MJ/kg	≥16.6 MJ/kg	18.2 MJ/kg	26.3 MJ/kg	22.2 MJ/kg

- En*plus* B standard for woody pellets i.e. premium pellets
- Cannot be directly marketed as equivalent to woody pellets, but closing in
- Application in coal powered power plants or in the steel industry

Process efficiency

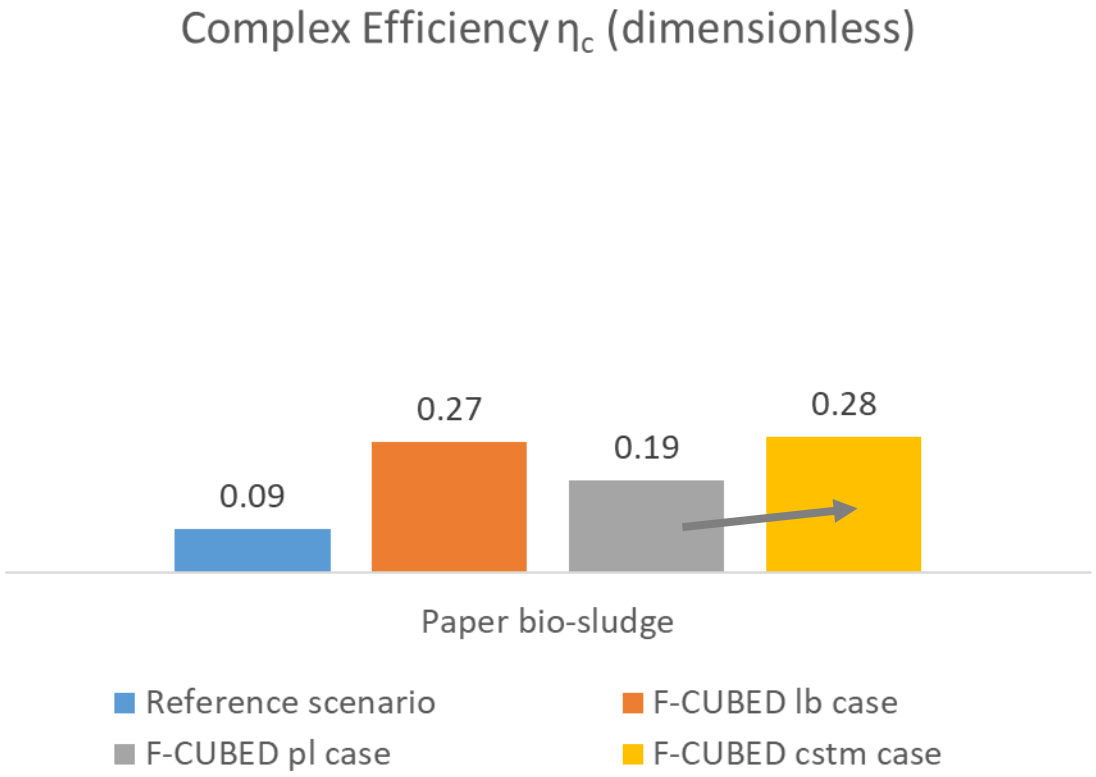


$$\text{Process efficiency} = \frac{\text{Energy in pellets}}{\text{Energy in feed}}$$

- Differences through amount of bio-organics dissolved
- Room for optimization for orange peels scenario
- Dissolved biomass can be used in anaerobic digestion

lb case = lab data
pl case = pilot plant data

Energy Efficiency (Paper bio-sludge)



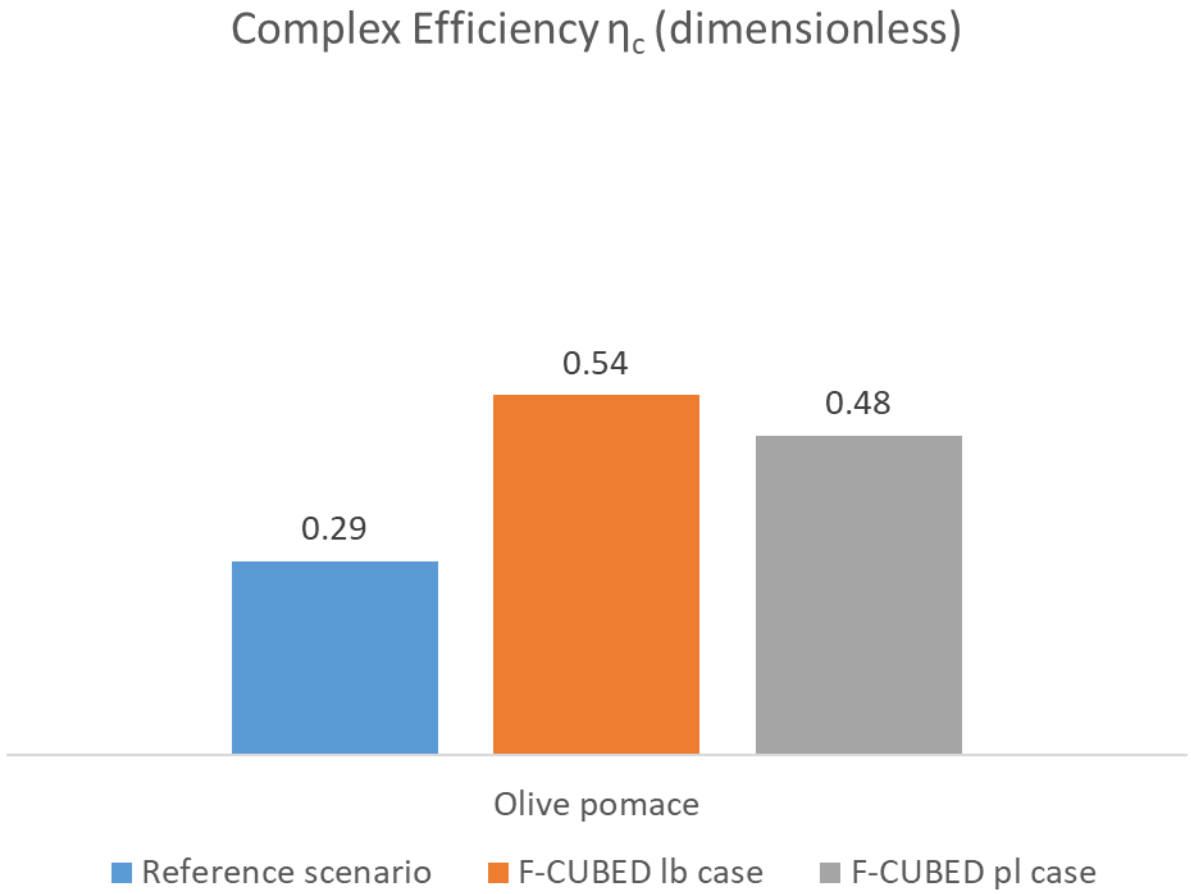
Complex efficiency (η_c)

- All input/output streams
- Primary energy based

- F-CUBED more energy efficient than reference (AD only)
- Lab (lb) case better than pilot (pl) because of drier cakes
- Custom (cstm) case is best:
  - ➔omit drying and pelletisation
  - ➔combustion of wet cakes

lb case = lab data
pl case = pilot plant data

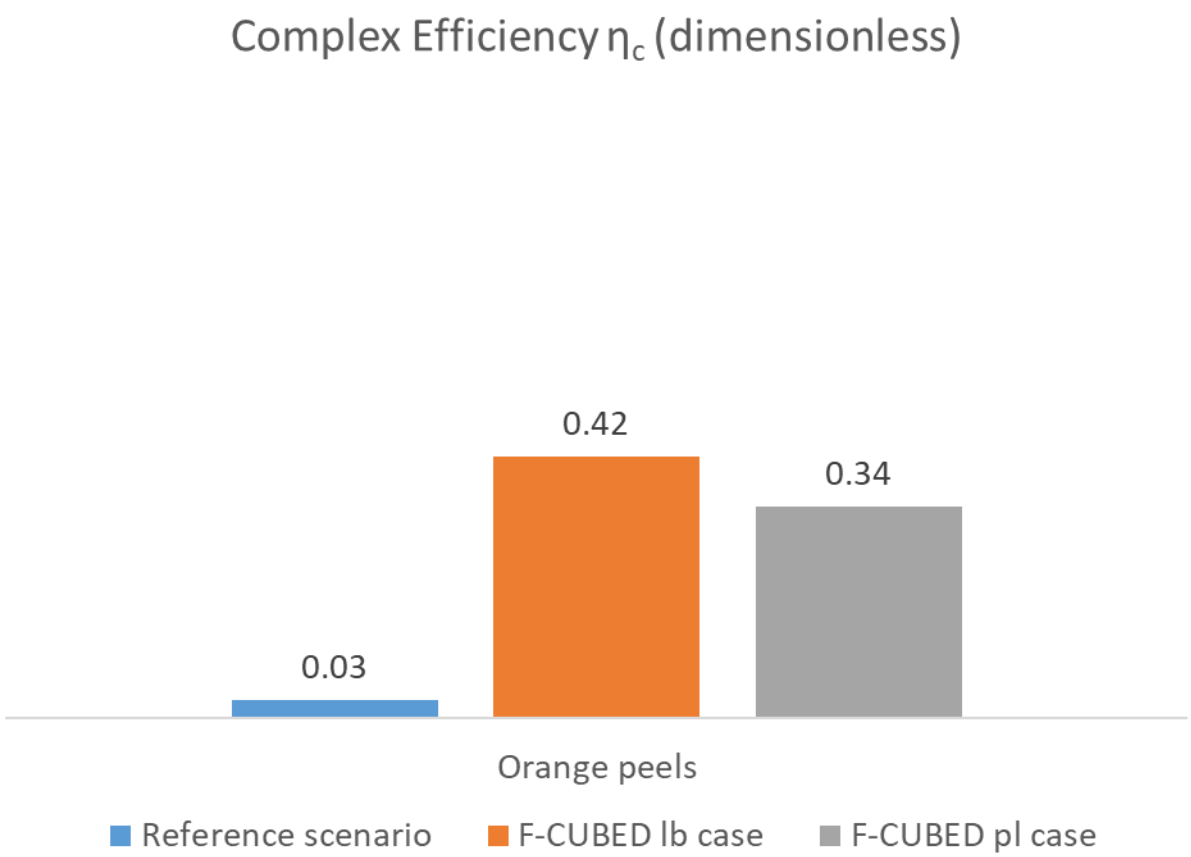
Energy Efficiency (Olive pomace)



- F-CUBED more energy efficient than reference scenario (AD only)

lb case = lab data
pl case = pilot plant data

Energy Efficiency (Orange peels)



- Reference scenario (AD only): Very low anaerobic digestibility (inhibition by limonene)
- Some room for optimisation from pilot case to lab case performance

lb case = lab data
pl case = pilot plant data

Conclusions

- Flexible process model available that translates experimental results into system performance

- Most relevant model parameters
  - Amount of organics going into solution
  - Pellet moisture content

- Model allows for bio-pellet quality assessment
  - Pellets best suited for power plants/steel industry

- F-CUBED system more energy efficient than reference scenarios for all feedstocks considered
  - Take anaerobic digestion step into account

- Custom scenario of paper bio-sludge with combustion of wet cakes much more efficient
  - Will also lead to significant cost reductions

THANK YOU

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