Techno-economic assessment of an olive mill waste biorefinery at different scales

K. Bampalioutas, D. Tsivas, L. Karaoglanoglou, **A. Vlysidis**

Laboratory of Organic Chemical Technology

School of Chemical Engineering

National Technical University of Athens

10th International Conference on Sustainable Solid Waste Management, Chania, 21-24 Ιουνίου, 2023

OUTLINE

- Aim of the study
- Introduction
  - Current situation in Greece (OMW)
  - Perspectives of this problem
- Design of an OMW Biorefinery
  - Recovery of high-added value products (residual oil & phenolic compounds)
  - A soil amendment
  - At different scales
- Techno-economic assessment
  - Profitability indicators & Scale-up TPC function
- Conclusions and next steps

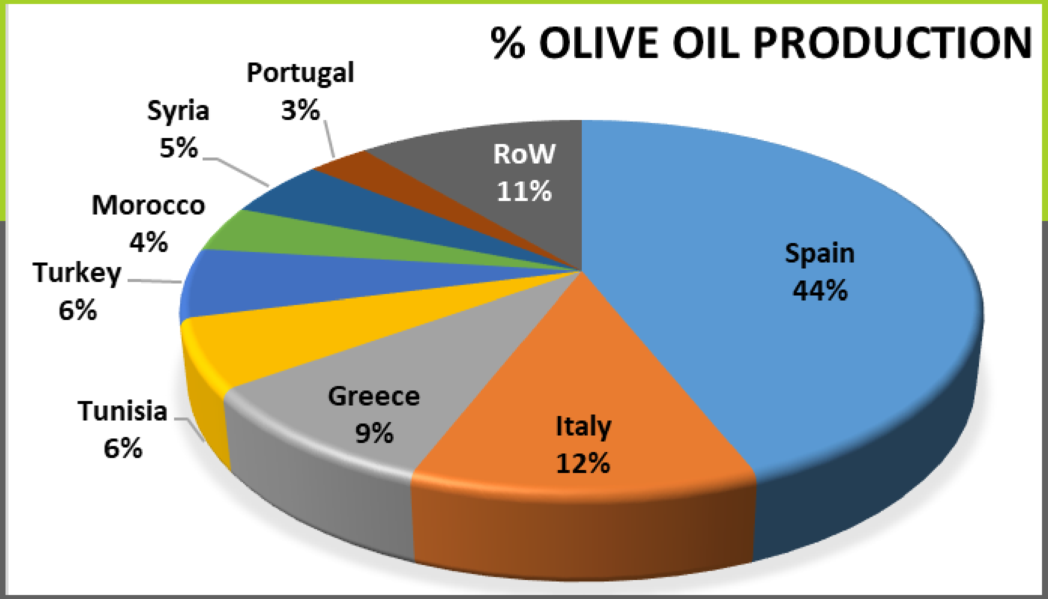
AIM OF THE STUDY

- Utilization of II-phase OMW
  - Recovery of high-added value products
    - Residual Oil
    - Phenolic Compounds
- Necessary steps so as to reduce any inhibitory phenomena in the bio-processes that follow
- Increase the sustainability of olive mills and olive pomace industries

OMW from a II-phase olive mill

- Development of a number of physicochemical & biological processes that lead to a series of products
- Zero-waste biorefineries

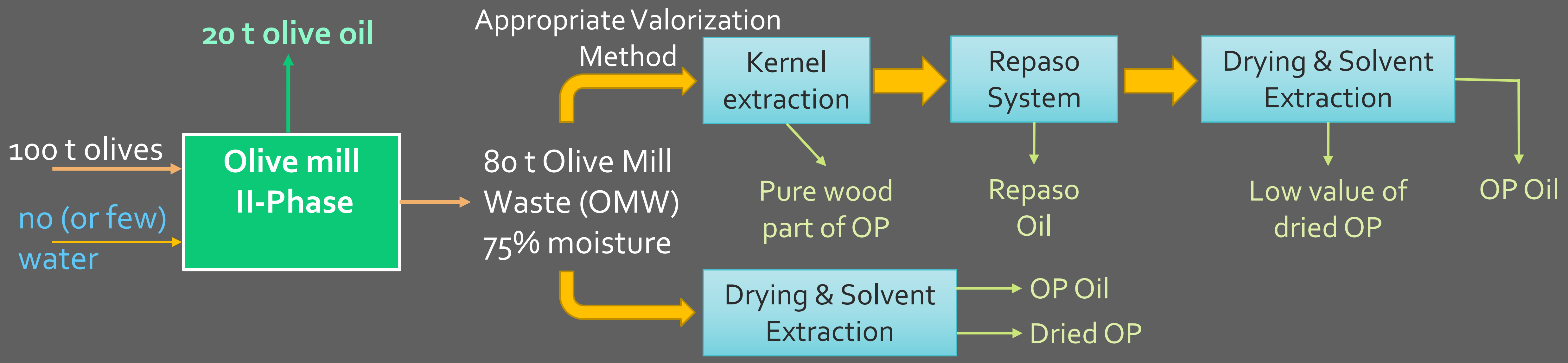
Introduction



- Olive oil production is one of the **most traditional** food industries of the Mediterranean area.
- Average annual **global production** 2.95 million tons (2010-2020).
- The vast majority in **Mediterranean** countries.
- The separation of olive oil is mainly carried out by **centrifugation** (II-phase or III-phase).
- There is a change in the Olive Mills Map in Greece
  - In 2009, ~2200 mills (>80% III-phase).
  - In 2020, ~1600 mills (~55% II-phase). → Adaptation to the Spanish model
- This percentage is likely to increase in the near future.
  - Last five years → investments in mechanical equipment concern exclusively II-phase technology.

FLOW DIAGRAM OF A II-PHASE OLIVE POMACE FACILITY

- ❑ II-Phase Olive Pomace is the **only by-product** → slurry material with high moisture



- ❑ Most of the **Olive pomace industries** in Greece are equipped to process III-phase OP instead of II-phase
- ❑ Direct drying of II-phase pomace in drum driers causes problems due to:
  - ❑ High moisture %
  - ❑ The presence of polysaccharides
- ❑ Short term solution: Mixing the II-phase with III-phase OP or with dried pomace (~30%).

CHARACTERIZATION OF THE WASTE

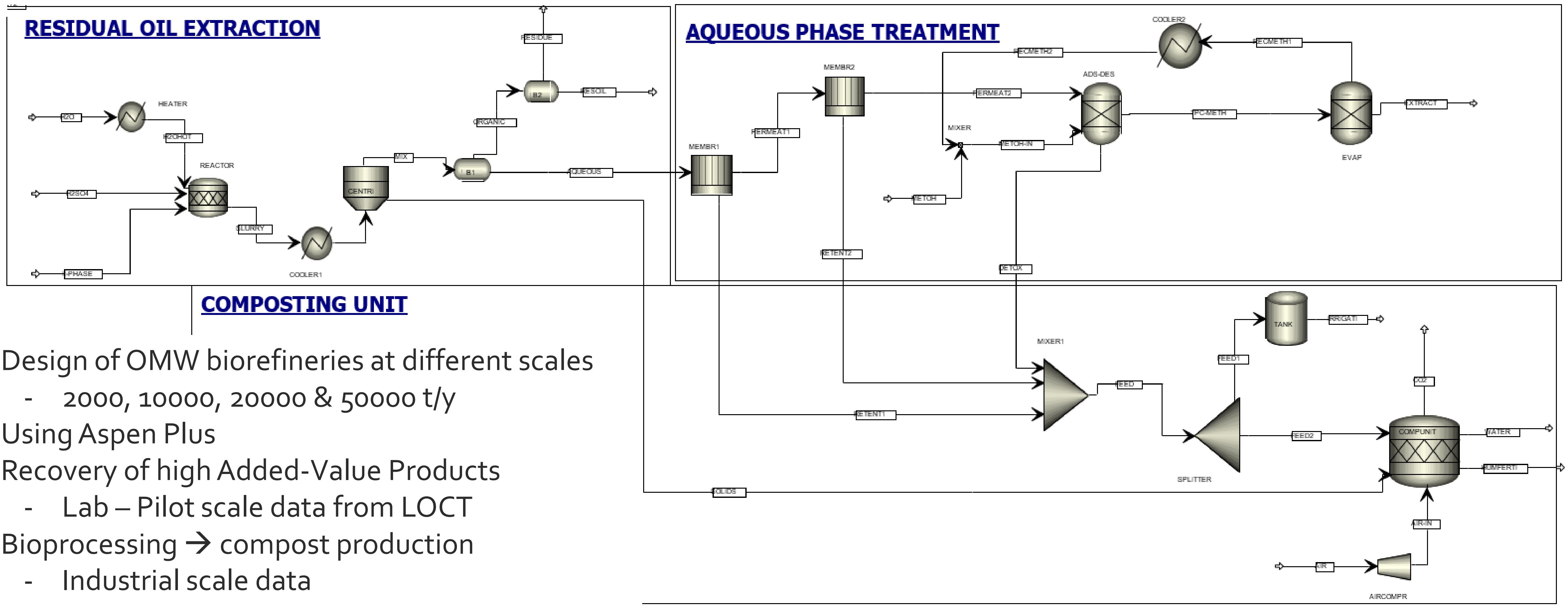
- Moisture: 78.0%
- COD: 89.2 kg/m^3
- Oil content: 10.2% (db)
- TPC: 10.0 g/L

Extract the phenolic compounds

Extract the residual oil

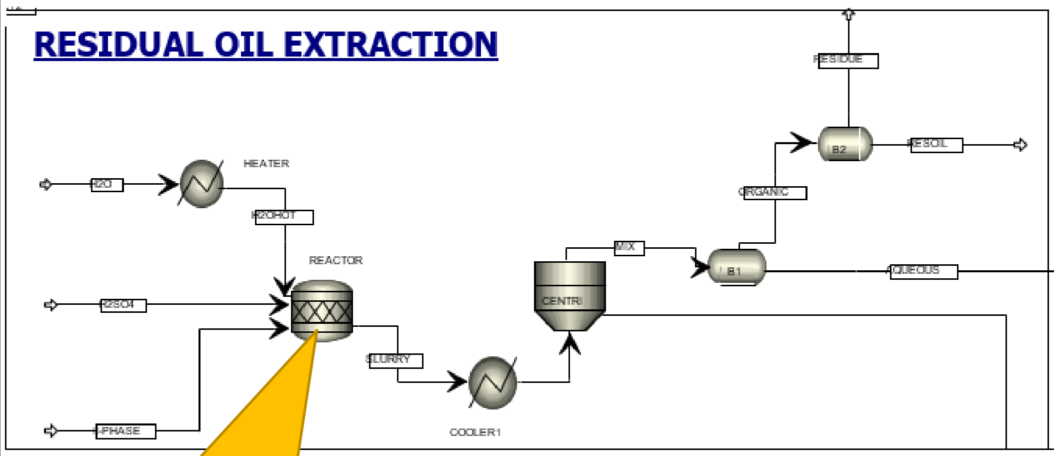
Olive Mill Waste

PROCESS DESIGN OF AN OMW BIOREFINERY

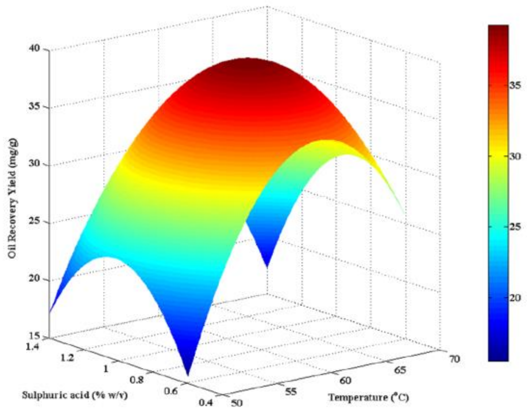


- Design of OMW biorefineries at different scales
  - 2000, 10000, 20000 & 50000 t/y
- Using Aspen Plus
- Recovery of high Added-Value Products
  - Lab – Pilot scale data from LOCT
- Bioprocessing → compost production
  - Industrial scale data

PROCESS DESIGN OF AN OMW BIOREFINERY - RESIDUAL OIL EXTRACTION



- Acidification with Sulphuric Acid, mild Temperature
- Optimisation with DoE.



Residual Oil

Aqueous phase rich in phenolic compounds

Solid fraction for composting

Optimum yield point:56 kg/t OMW (db)

Annual productivity:

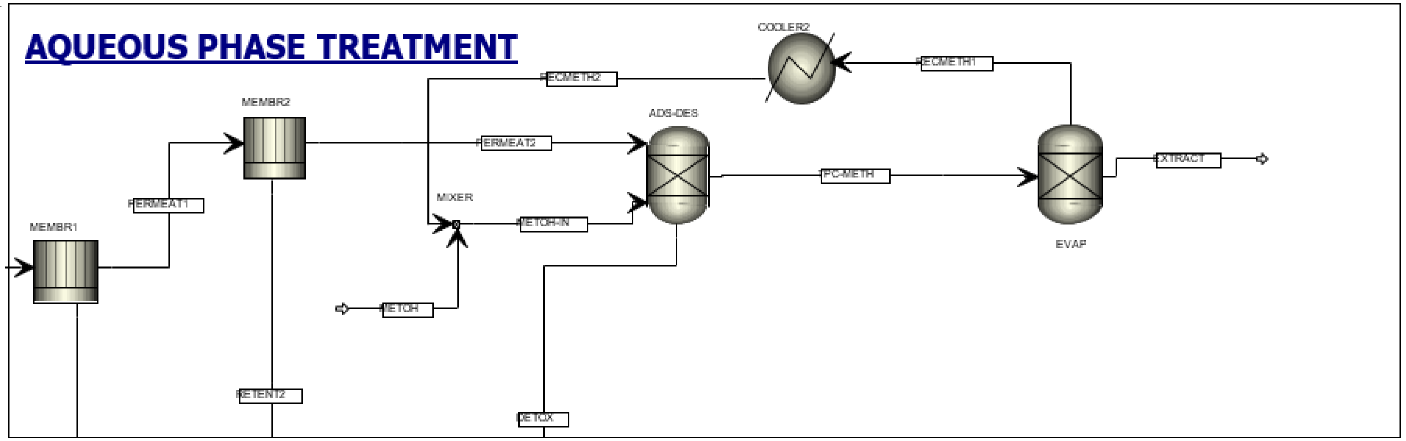
- 22.1 t/y for 2000 tons
- 100.7 t/y for 10000 tons
- 201.3 t/y for 20000 tons
- 503.4 t/y for 50000 tons

PROCESS DESIGN OF AN OMW BIOREFINERY - PHENOLIC COMPOUNDS

Optimum yield point:30.6 kg-TPC/t OMW

Annual productivity:

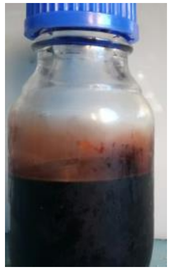
- 31.4 t-Extract/y for 2000 tons
- 143.5 t-Extract/y for 10000 tons
- 287.1 t-Extract/y for 20000 tons
- 717.7 t- Extract/y for 50000 tons



Micro & ultrafiltration

Ion-Exchange Resins

Evaporation



Extract rich in Phenolic Compounds (~250 kg-TPC/m³)

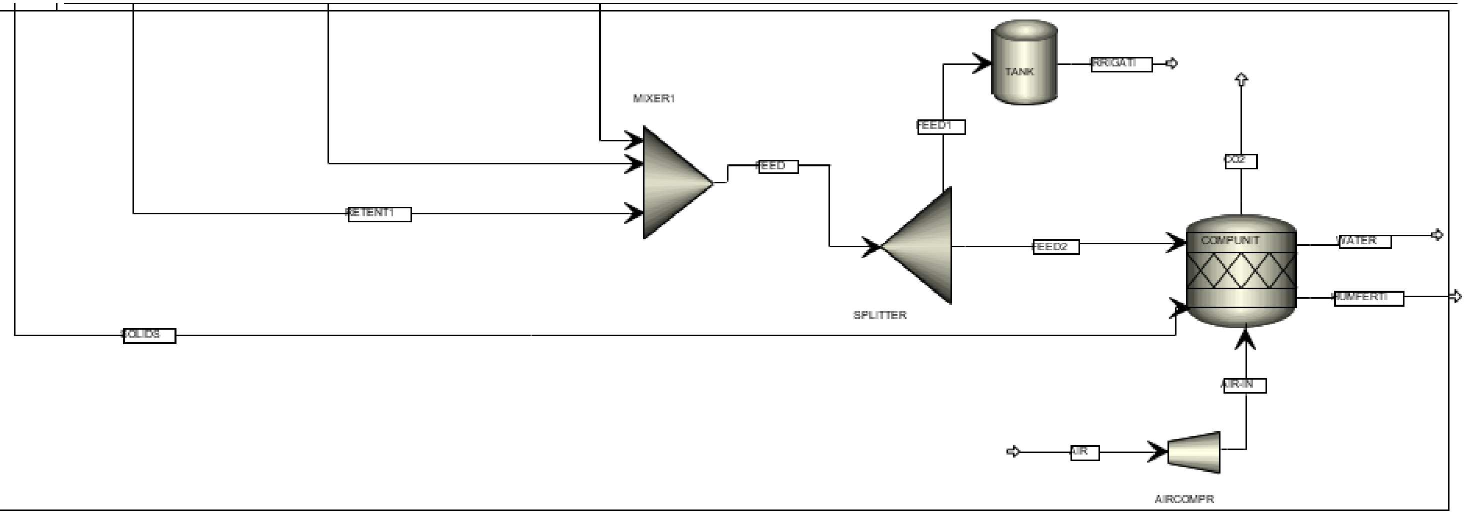
PROCESS DESIGN OF AN OMW BIOREFINERY - COMPOST PRODUCTION

All residuals streams (solid & liquid) end up in the composting process.

Annual productivity:

- 283 t/y for 2000 tons
- 1290 t/y for 10000 tons
- 2580 t/y for 20000 tons
- 6450 t/y for 50000 tons

COMPOSTING UNIT



TECHNO-ECONOMIC ANALYSIS METHODOLOGY

Development of the Process Flow Diagrams

↓

Sizing of the equipment and obtaining their characteristic values

↓

Calculation of the equipment cost through empirical costing equations

↓

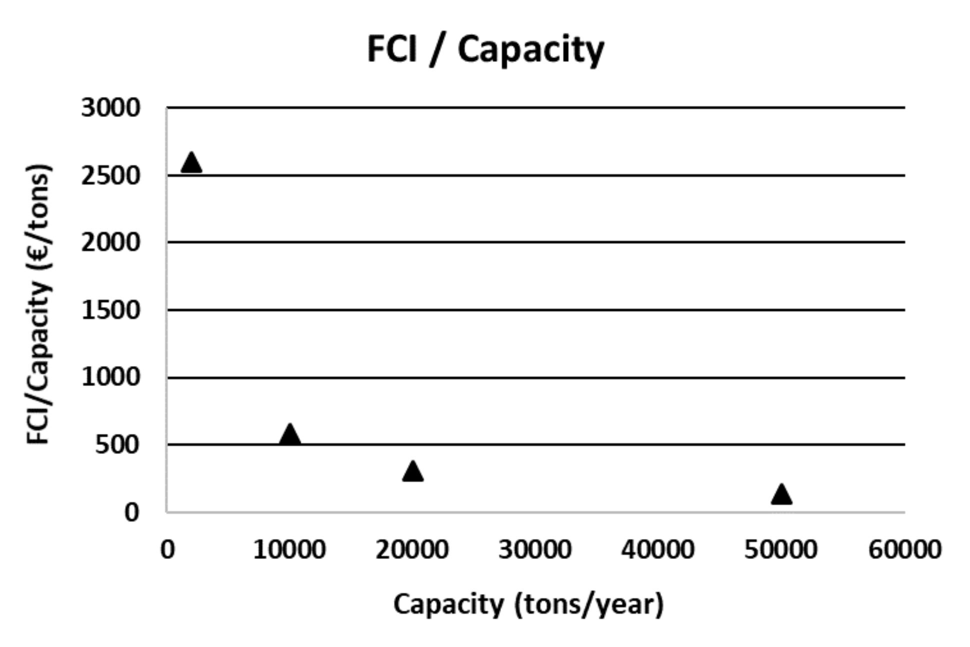
Conversion to 2022 prices by using the CEPCI (CHEMICAL ENGINEERING PLANT COST INDEX)

↓

Calculation of the installation cost (C_{BM}) via installation factors F_{BM}

↓

Calculation of the fixed capital investment $FCI=1.6*C_{BM}$



The Total Production Cost

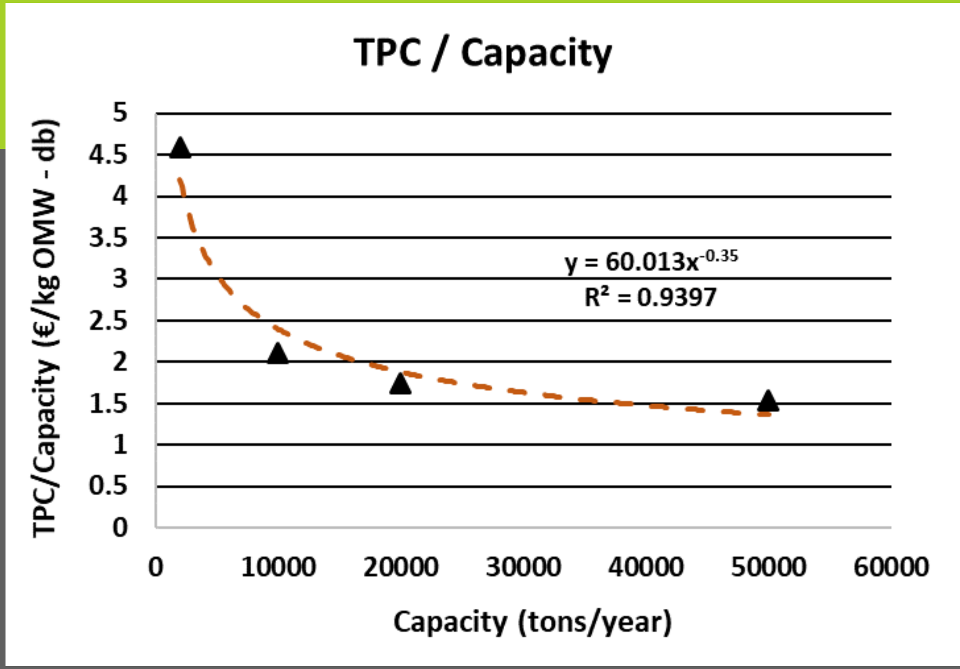
$$TPC_{woD} = 0.18FCI + 2.73C_{OL} + 1.23(C_{RM} + C_{UT} + C_{WT})$$

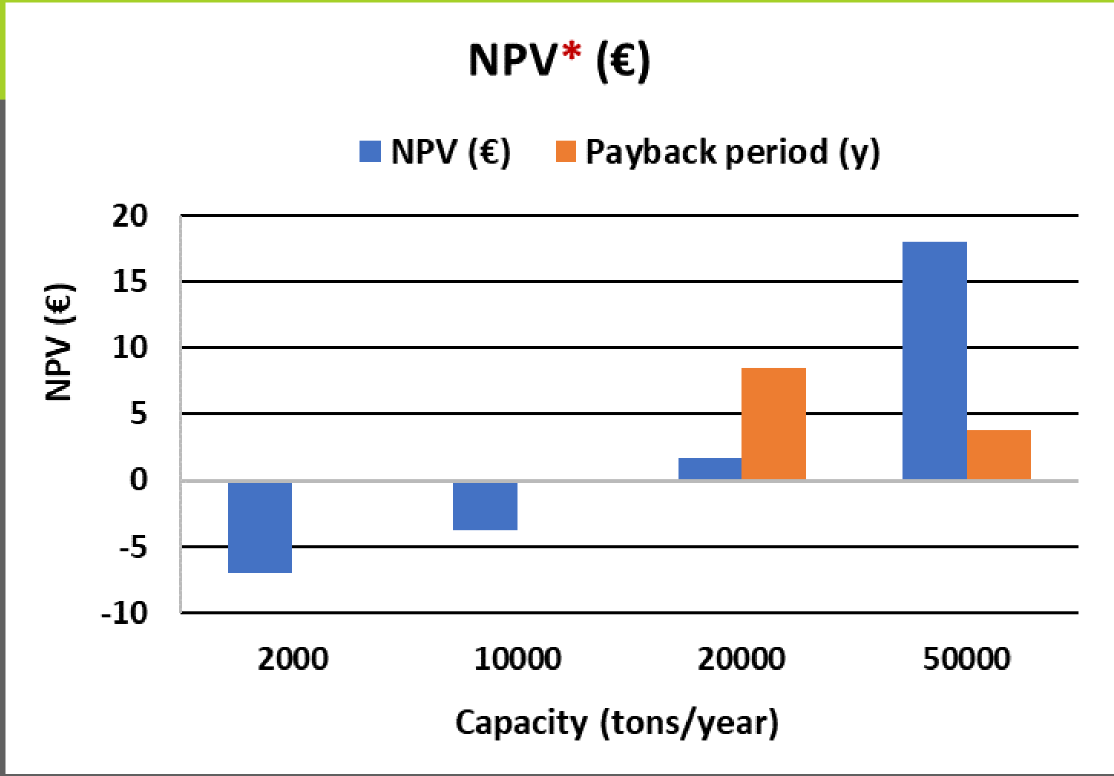
Annual Capacity (t)	FCI (M€)	C_{RM} (M€/y)	C_{UT} (M€/y)	C_{OL} (M€/y)	C_{WT} (M€/y)
10,000	5.82	1.67	0.41	0.34	0.09

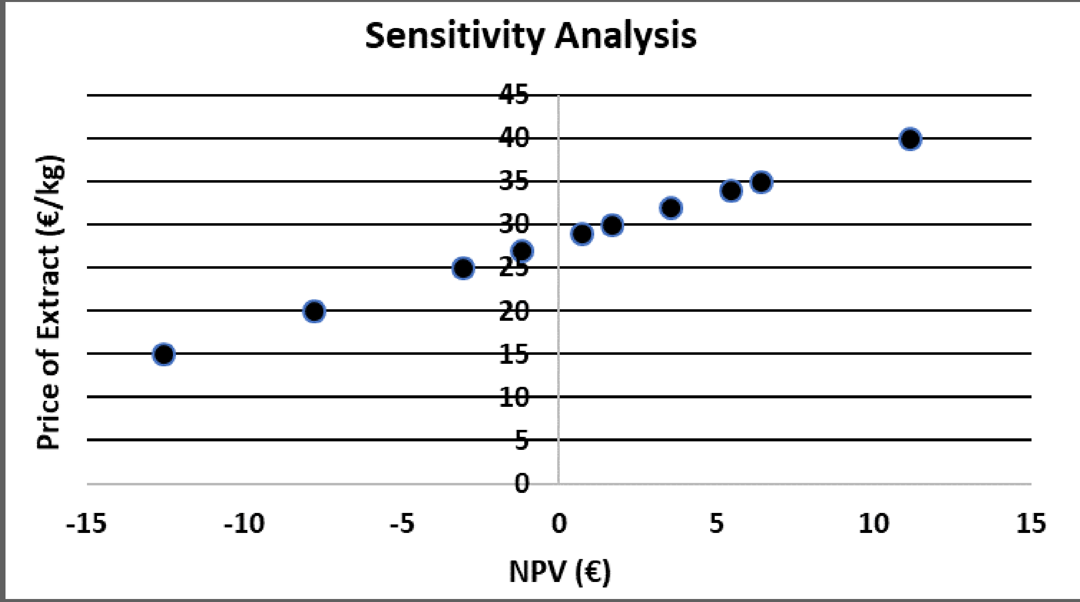
TPC = 4.64 M€/y ή TPC = 2.11 €/kg OMW (db)

Ref: Peters M.S., Timmerhaus K.D, West R.E., Plant Design & Economics for Chemical Engineers, 2003, NewYork, USA

RESULTS FROM THE TECHNO-ECONOMIC ANALYSIS







MSP (€/kg)
28.25

*Present value analysis of cash flows

Interest Rate	10%
Depreciation method	7-years MACRS
Time of construction	3 years
Tax rate	40%
Equity (own funds)	100%
Lifespan of investment	10 years

CONCLUSIONS AND FUTURE ACTIONS

- We designed an OMW Biorefinery for the production of a spectrum of final products under the concept of circular economy @ Different scales
- Profitability increases with plant capacity
  - Unit TPC and FCI are reduced
  - Positive NPV values and good PBPs @ 20 & 50 ktons
- NPV is affected from the market value of phenolic compounds
  - MSP ~ 28.3 €/kg for the 20 ktons plant capacity
- Go back to the lab and optimize the desorption process
- Development of innovative bioprocesses with the liquid streams for production of bioplastics, biochemicals & bioenergy.
- Collaboration with olive mills & olive pomace industries for application at larger scales
- Collaboration with a cosmetic industry for the use of PC Extract in sun creams.

THANK YOU FOR YOUR ATTENTION

Acknowledgements

ORGANOHUMIKI THRAKIS