Session XIII: Biofuels & Biobased Products

LIVEWASTE

CYPRUS 2016

4th International Conference on Sustainable Solid Waste Management

Sustainability assessment for the production of bio-based products using by-product streams derived from the pulp and paper industry

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23rd – 25th June 2016

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Our Research Group

Biorefinery development based on renewable resources

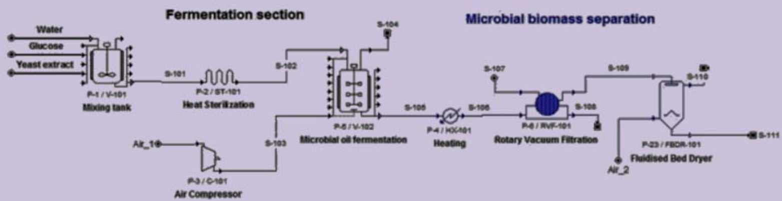
Valorisation of renewable resources

Agricultural crops and residues

Industrial wastes and by-product streams

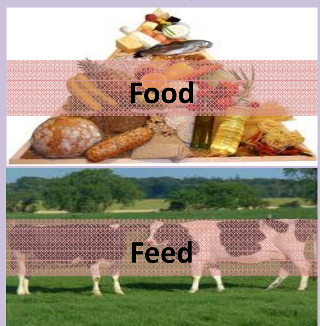
Food waste and by-products

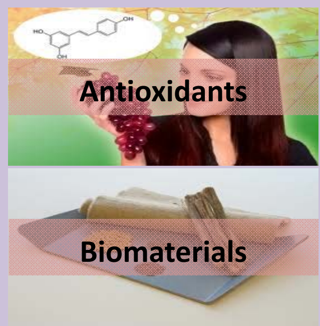
Biorefinery development

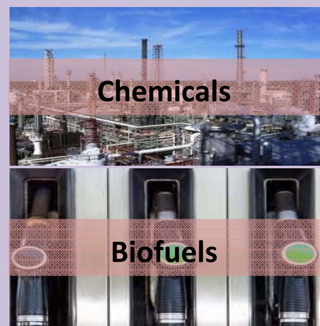


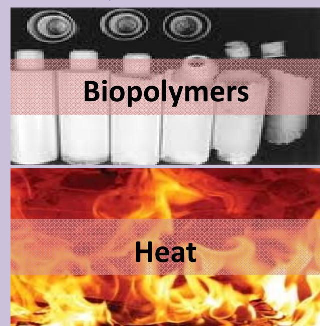
- White biotechnology
- Bioprocess / biorefinery engineering
- Bioprocess / biorefinery design
- Bioprocess optimisation

Added-value products









Fermentation cases of Agricultural wastes integrated in biorefinery schemes

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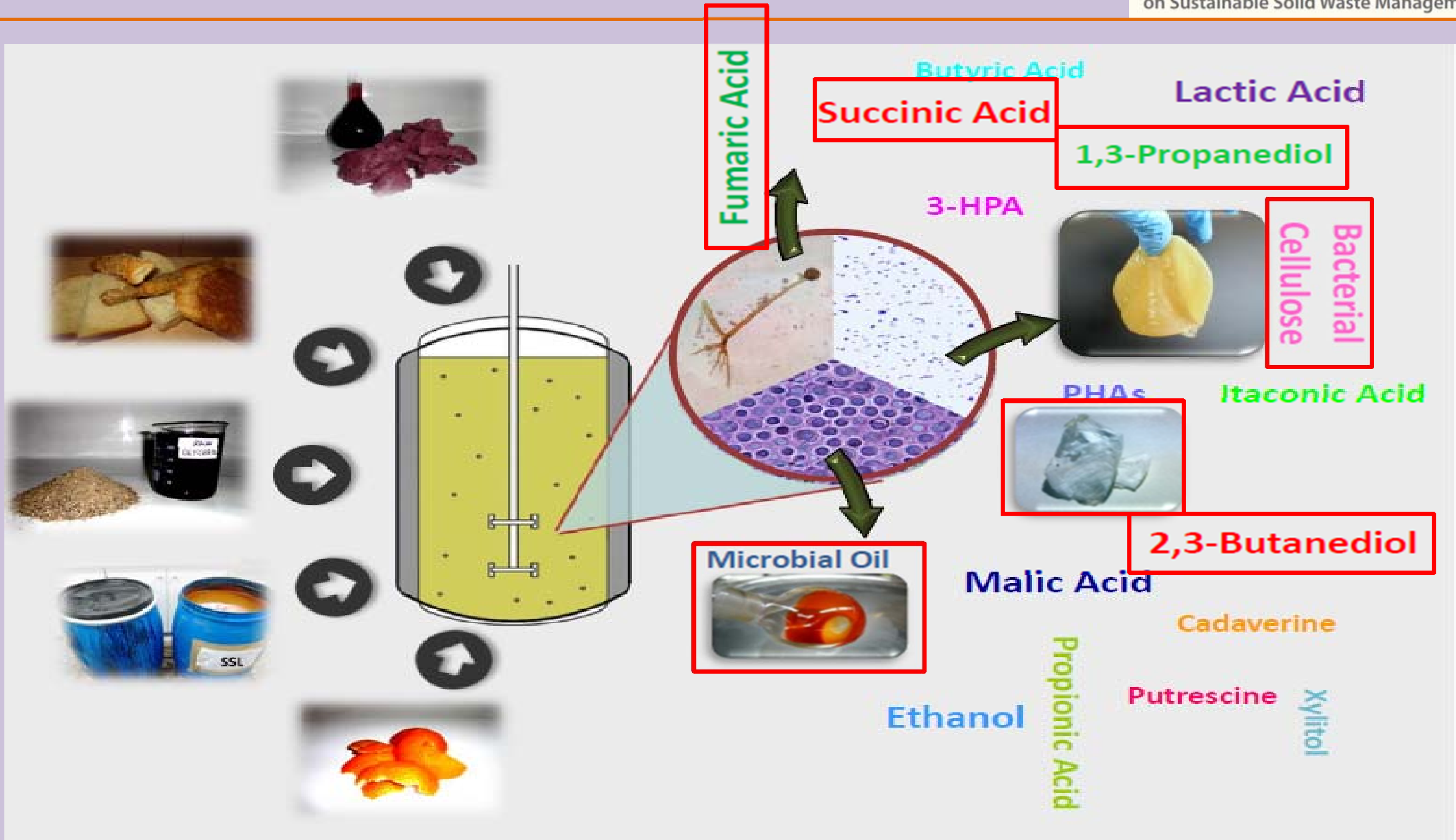
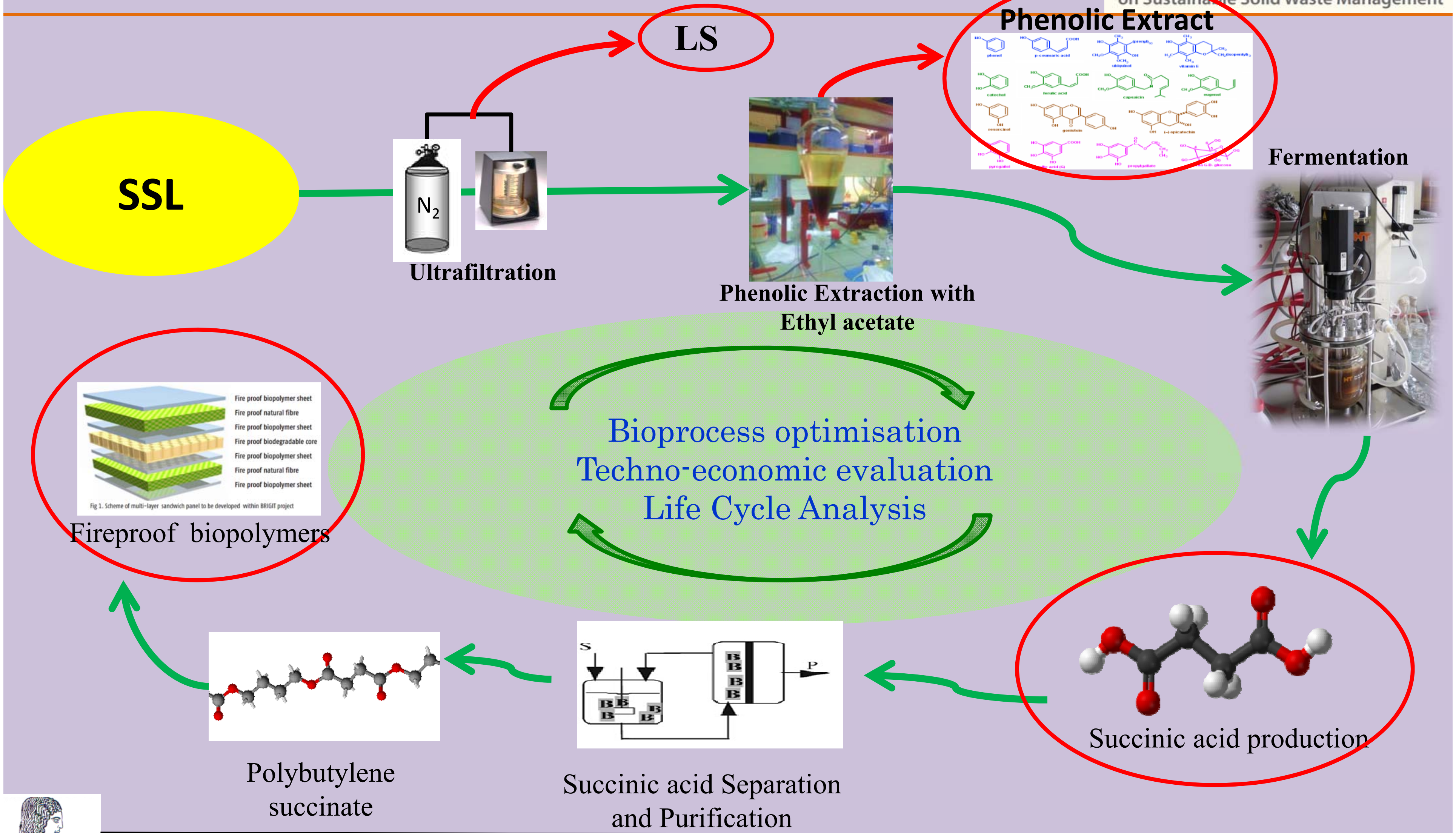


A.A. Koutinas, Chem. Soc. Rev., 2014,43, 2587-2627

BRIGIT Project: Valorising SSL from pulp and paper mills



SSL Production in Pulp and Paper Industry

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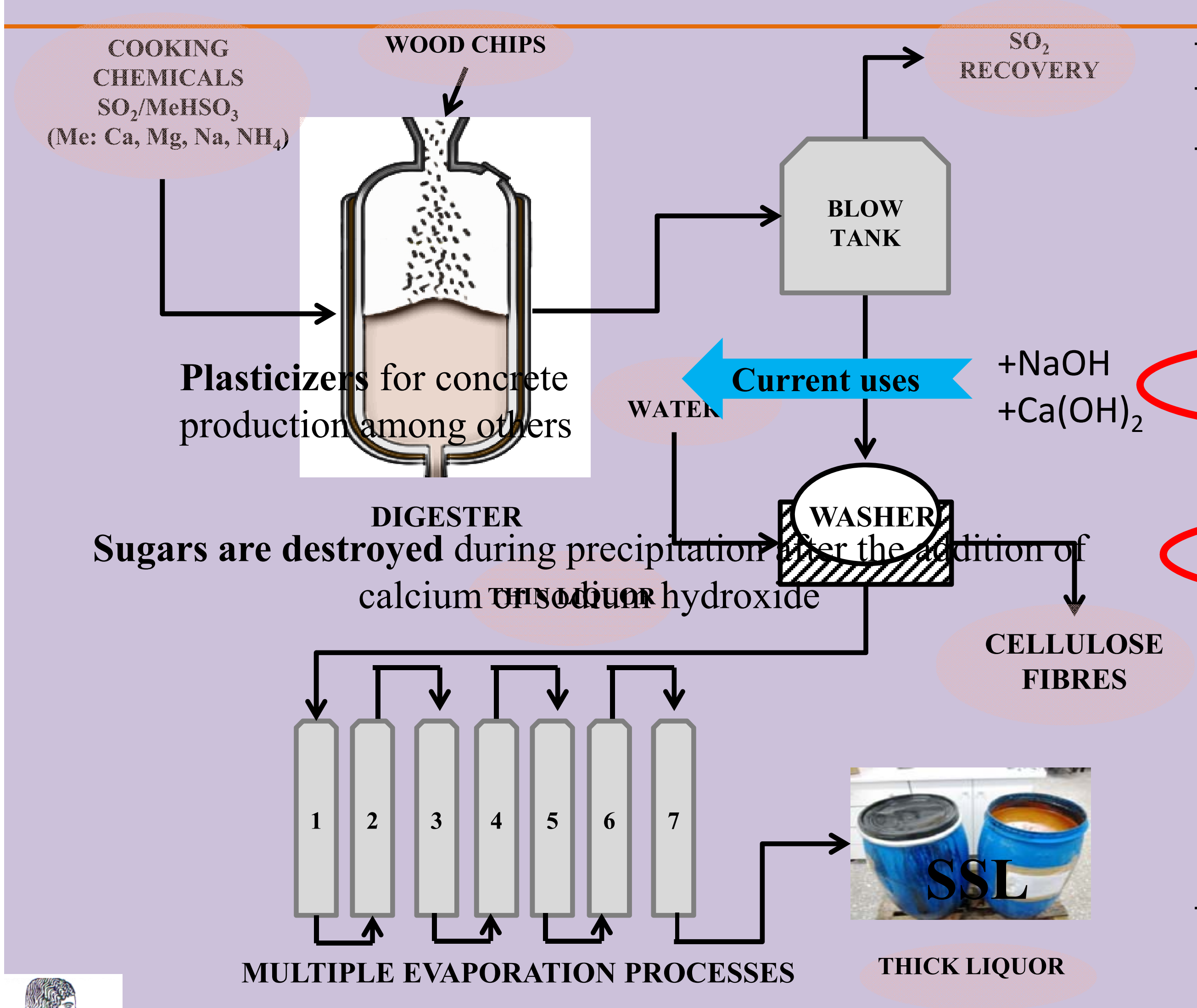
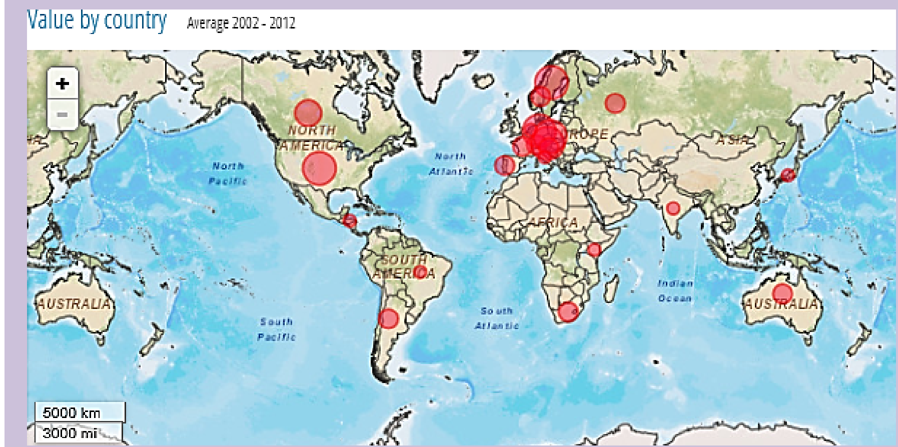
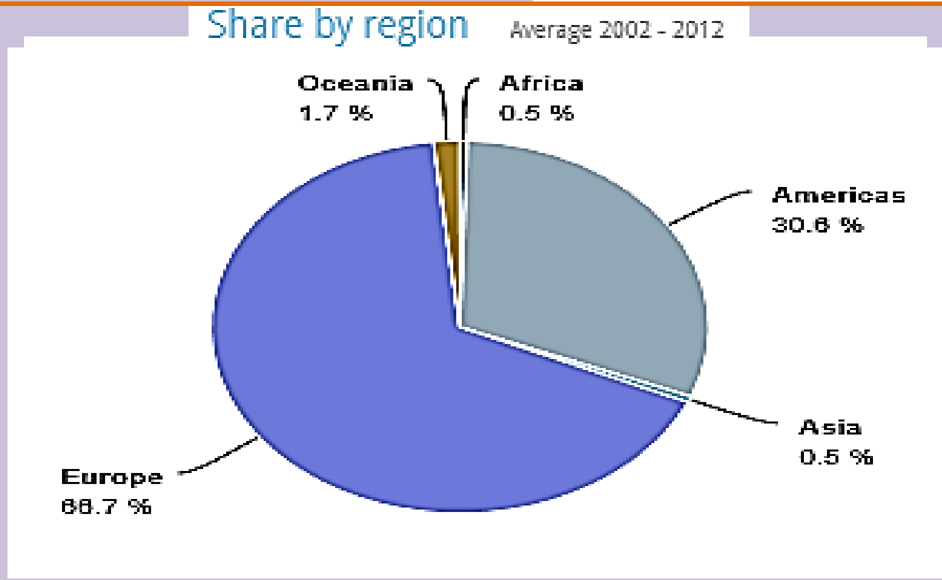


SSL Characterisation	Value	St Dev
pH	2.7	
Density (g/mL)	1.277	0.007
Viscosity (cP)	552	167
Dry Matter (g-DM/L)	816.5	0.6
Lignosulphonates (g/L)	458.8	2.7
Ash % (g/g-DM)	8.62	0.55
Phenolics % (g/g-DM)	1.55	0.04
Carbohydrates (g/L)	176.41	
Xylose (g/L)	128.08	0.59
Galactose (g/L)	21.47	5.50
Glucose (g/L)	19.27	0.39
Mannose (g/L)	7.41	1.30
Arabinose (g/L)	0.18	0.05
Acetic Acid (g/L)	6.91	0.49

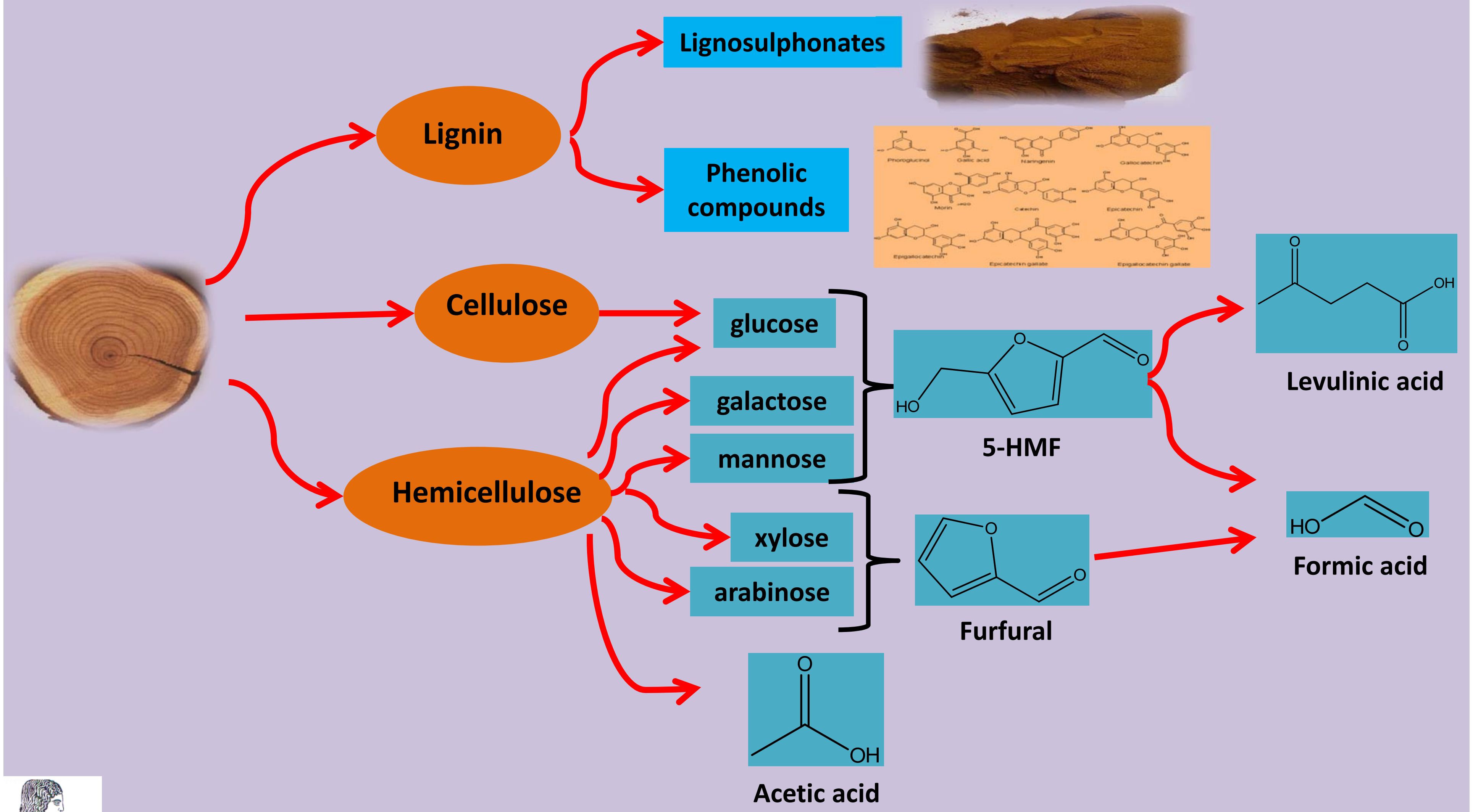
Worldwide production quantity of bleached sulphite pulp in the last decade





- Global **annual production** of bleached sulphite pulp: 3,570,476 t/yr (FAO, 2012) →14% increase since 2009
  - Annual production in United States of America: 989,074 t/yr (FAO, 2012) → 21% increase since 2009
  - Annual production in South America: 211,000 t/yr (FAO, 2012) → 74% increase since 2009
  - Annual production in European region: 2,056,902 t/yr (FAO,2012) → 0,01% increase since 2009

Formation of Sugars & Inhibitors During the Process



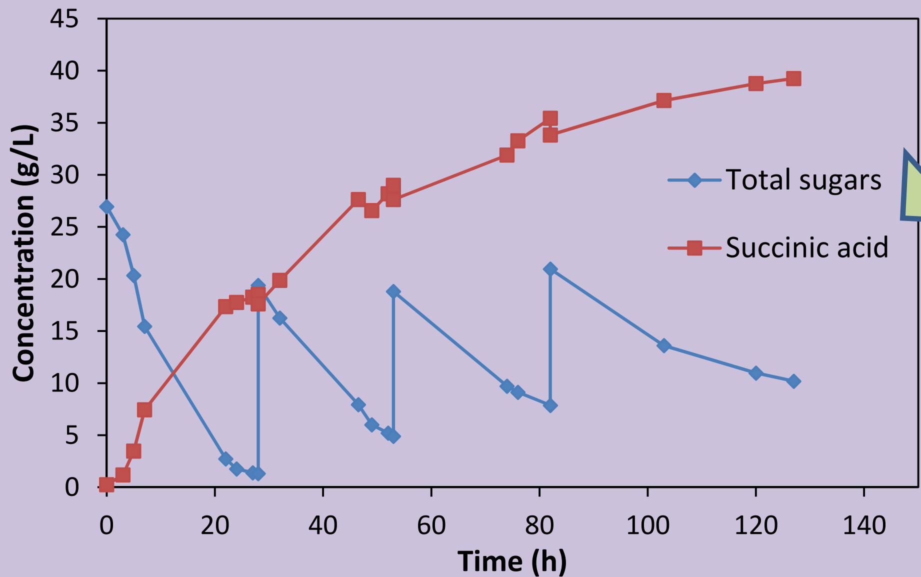
Detoxification / Pretreatment and fermentation of SSL

SSL

Ultrafiltration

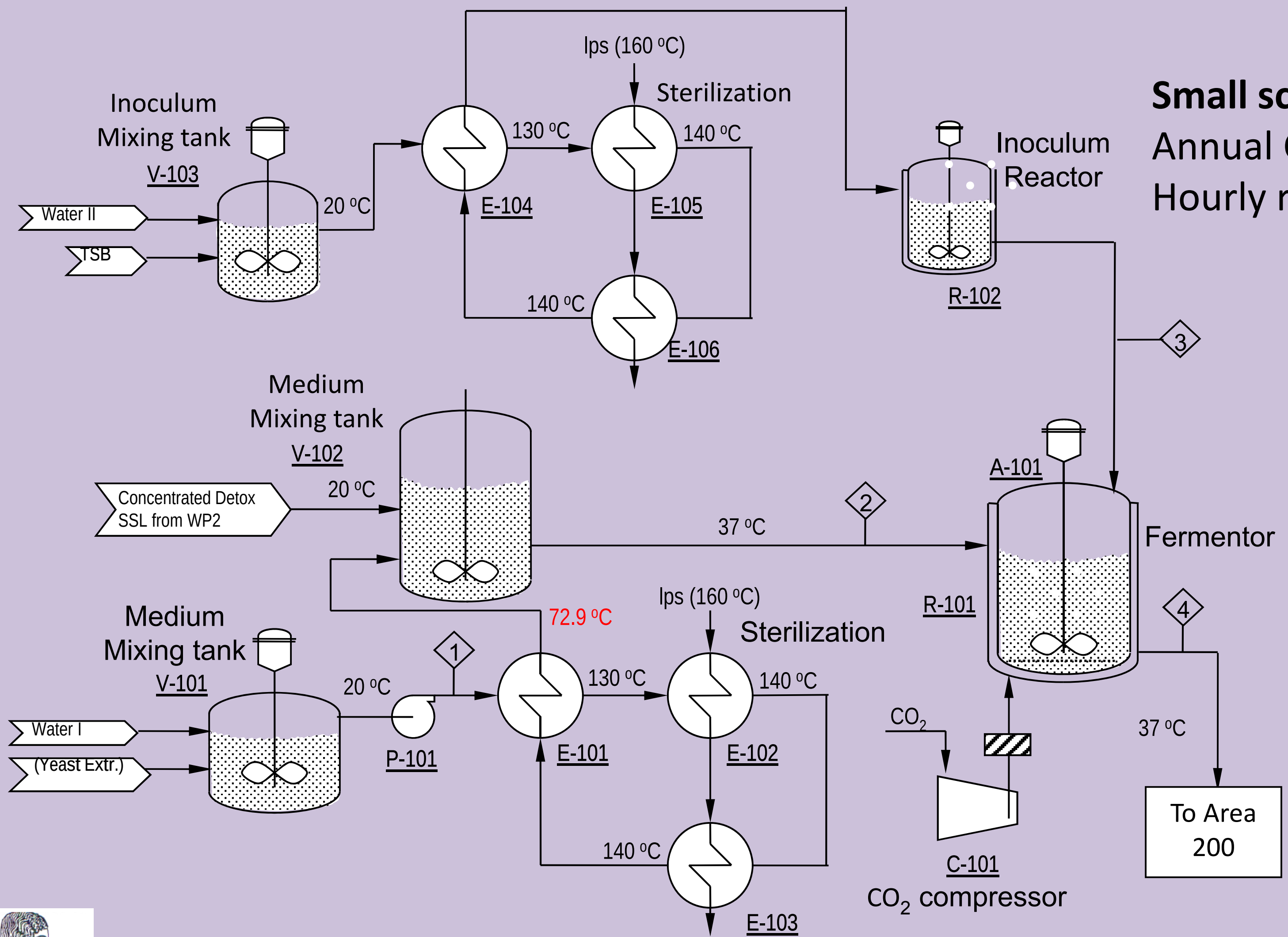
Phenolic Extraction with Ethyl acetate

- ☺ 0.63 g-SA/g yield
- ☺ Low by-product formation
- ☺ SA productivity 0.31 g/L/h (0.5 g/L/h @ 50 h)
- ☺ ~ 40 g/L final SA



Fermentations
A. succinogenes
B. succiniciproducens

Process Design of the SA production & purification of SA from SSL

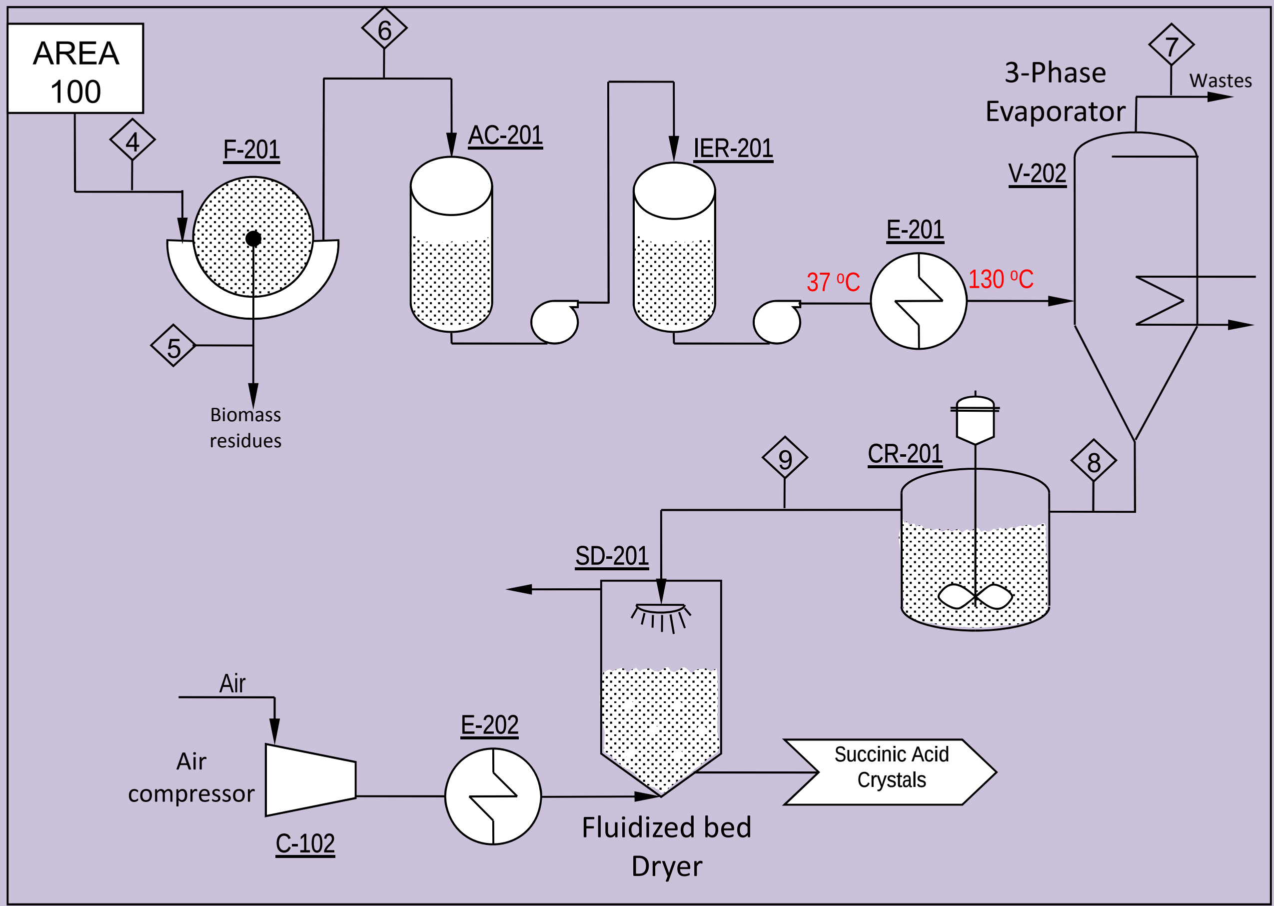


Small scale plant

Annual Capacity of SSL: 15 kt

Hourly rate of 2.14 t/h

Process Design of the SA production & purification of SA from SSL (cont’)



2 ktons of SA / year
Hourly rate: 300 kg/h

Using process simulation software UNISIM
Simulation of SA production & purification

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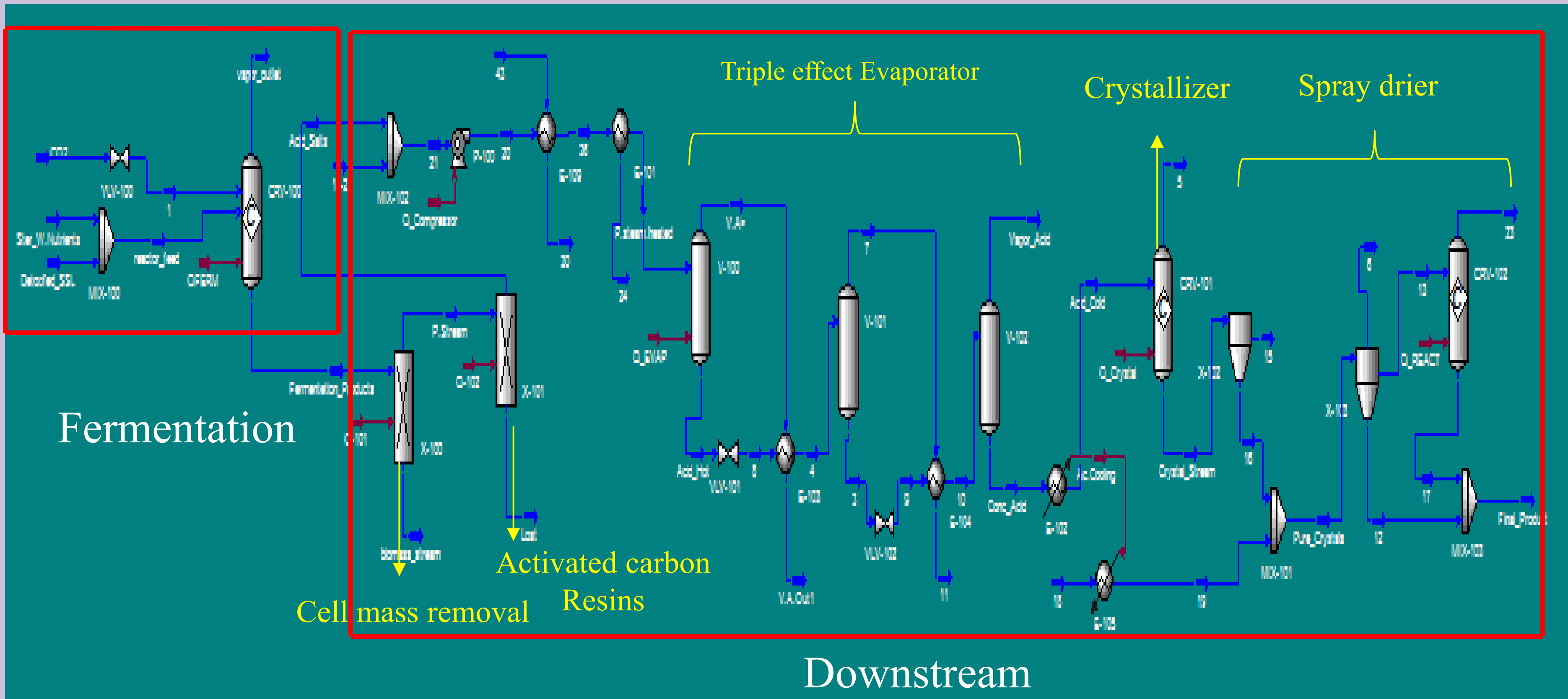


Heat Integration

- Combine hot and cold stream
- Energy minimization
- 65% less consumption of steam

Techno-economic evaluation of SA bioprocess

Development of the Process Flow Diagrams

Sizing of the equipment and we find their characteristic values

Calculation of the equipment cost through empirical costing equations

Conversion to 2015 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 $FCI=1.6*C_{BM}$

- C_{BM} = M$ 9.7
  - 47% Triple effect evaporator
  - 37% the three fermenter
  - Together with their agitators
- FCI = M$ 15.6

- Utility Cost was remarkable
  - High requirements for steam
  - M$ 0.85 per year

The Total Production Cost:

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

TPC = M$ 11.1 per year

5.39 $/kg-SA produced

Current prices:

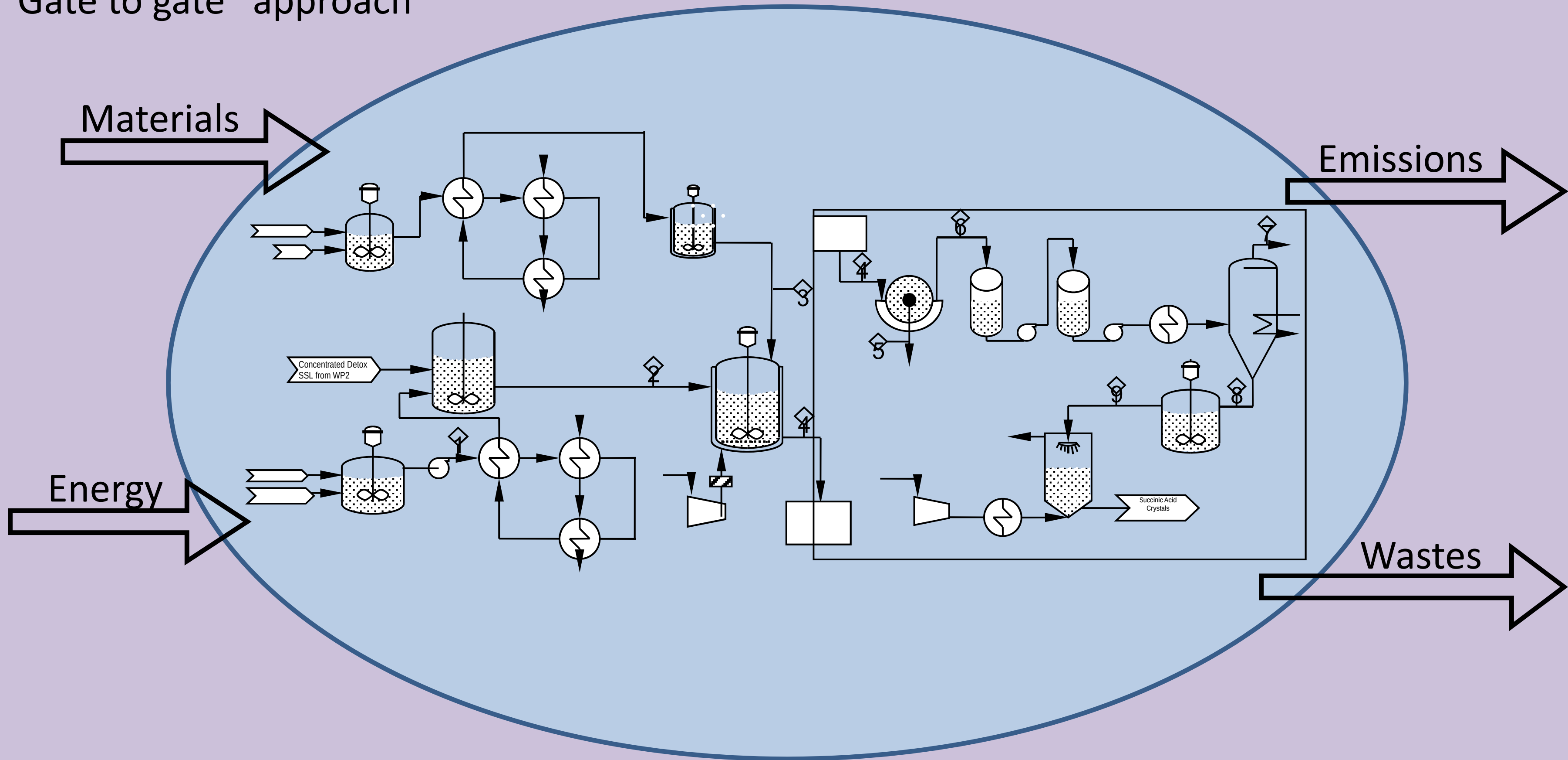
2.94 for biobased SA *

2.5 for petroleum derived SA *

LCA for the production and purification of SA

System boundaries

"Gate to gate" approach



LCA of SA bioprocess

Gabi software from PE International

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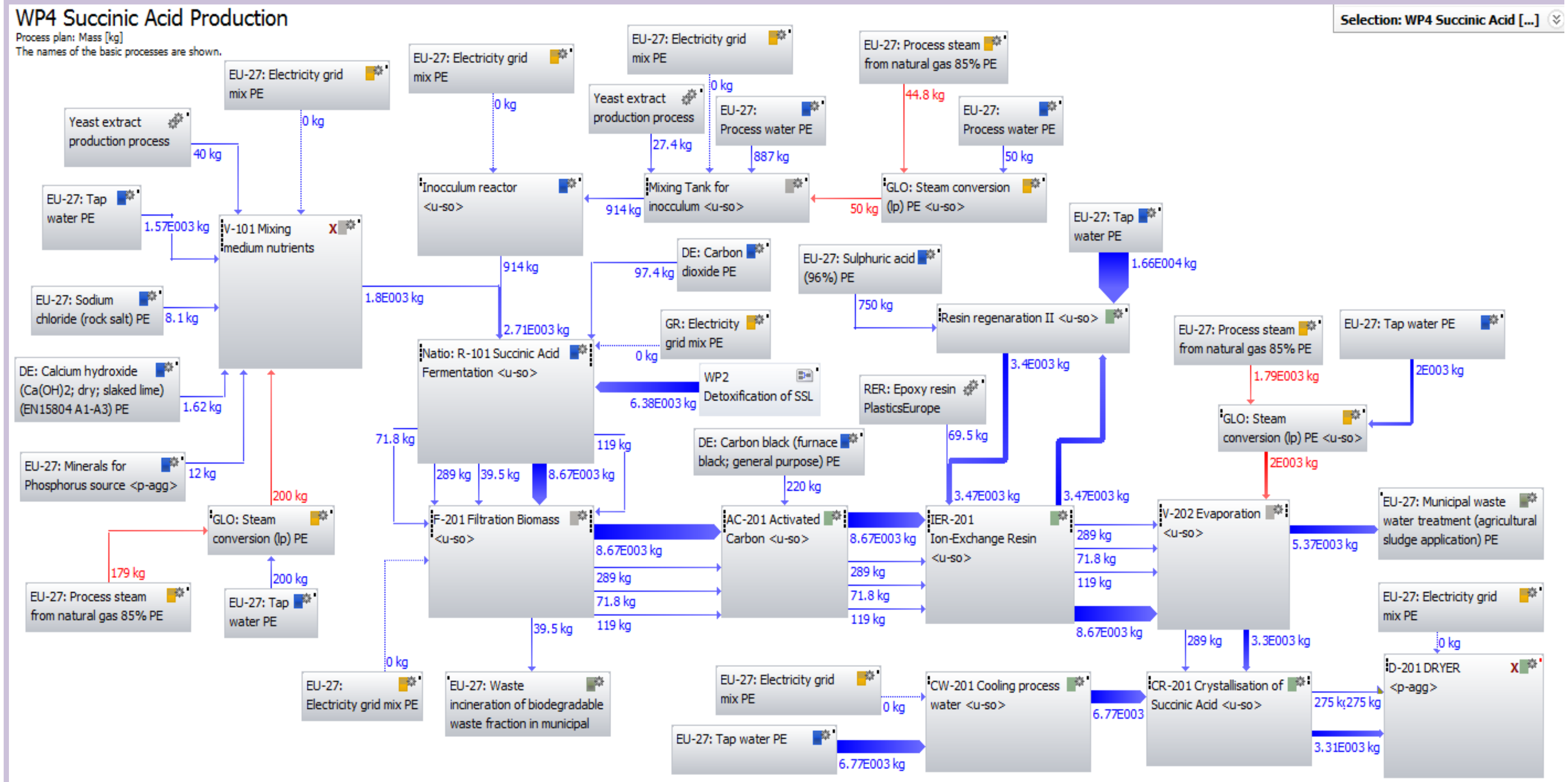

Identification of “hot spots”: SA Production and Recovery

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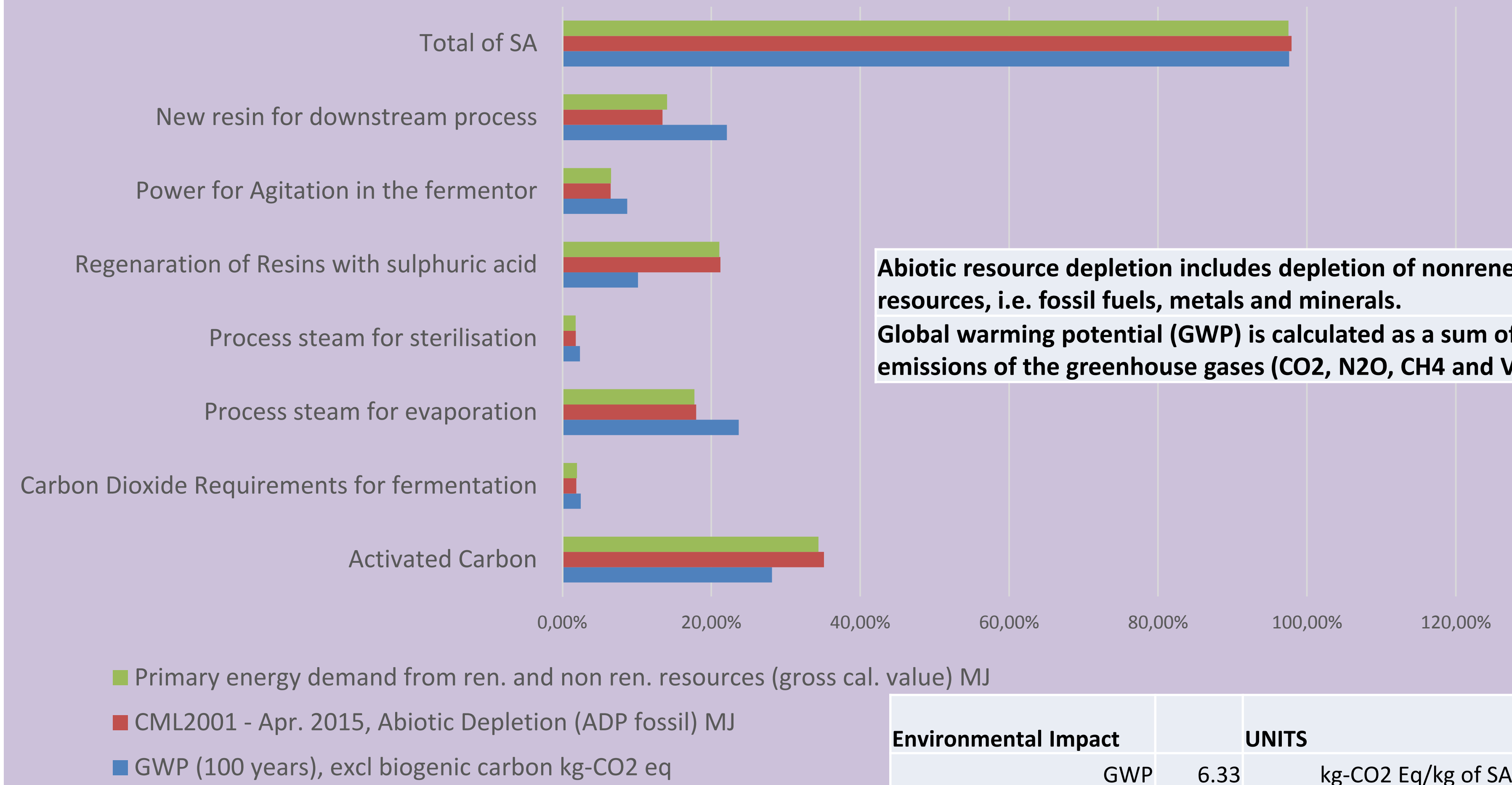

Abiotic resource depletion includes depletion of nonrenewable resources, i.e. fossil fuels, metals and minerals.

Global warming potential (GWP) is calculated as a sum of emissions of the greenhouse gases (CO_2, N_2O, CH_4 and VOCs)

Environmental Impact		**UNITS**
GWP	6.33	kg-CO2 Eq/kg of SA produced
ADP (MJ)	136.06	MJ /kg of SA produced
Energy Demand (MJ)	155.22	MJ /kg of SA produced

Main Conclusions & Future recommendations

- SSL is a by-product of the pulp and paper industry that can be used as a substrate in microbial fermentations
  - Needs to be pretreated first (remove the inhibitors)
  - Extract LS by nanofiltration
  - Extract phenolic compounds by solvent extraction
- Succinic acid can be produced in high yields and adequate productivities and final SA concentrations
- Techno-economic evaluation gave a higher TPC of SA from current SA costs
  - 5.3 instead of 2.9 $/kg
  - Under the same order of magnitude
  - Scale up designs (2→10→50 ktons) will significantly decrease the TPC
- The carbon footprint of the SA process showed a 6.3 kg-CO_2 Eq./kg-SA
  - Mainly due to the downstream process
  - The LCA results will be compared with petrochemical SA production

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Thank you for your attention

The AUA team

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The research leading to these results has received funding from the European Union’s Seventh Framework Program for research, technological development and demonstration under grant agreement nº 311935

Phenolic compounds

- **Determination of the main phenolic compounds in the extracts by HPLC - DAD**

Phenolic compound (mg/L)	pH =2 ratio 1:3 v/v	pH =3.4 ratio 1:3 v/v
Gallic acid	1038	525
Isorhamnetin	41	21
Syringic acid	252	106
Syringaldehyde	32	127
Vanillic acid	50	17.8
Acetosyringone	16	-
Lariciresinol	142	-
Ellagic acid	1165.5	534
Caffeic acid	3.2	4
Vanillin	115	120
Catechin	127.6	53