GOBIERNO DE ESPAÑA
MINISTERIO DE ECONOMÍA, INDUSTRIA Y COMPETITIVIDAD
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

SMALL-SCALE BIOREFINERIES BASED ON OLIVE TREE PRUNING BIOMASS

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1. Introduction

Products/Residues generated in the olive oil industry

- Olive tree is one of the main crops in Mediterranean countries, specially in **Spain**.
- Approximately, **2.3 millions hectares** of olive are cultivated in Spain

- 1 hectare of olive tree
  - 2,500 kg olives
    - 500 kg olive oil
    - 2,000 kg pomace
      - 400 kg stones
      - 40 kg pomace oil
      - 260 kg extracted pomace. “Orujillo”
    - 1,300 kg wastewater
  - 1,500 kg olive tree pruning (OTP)

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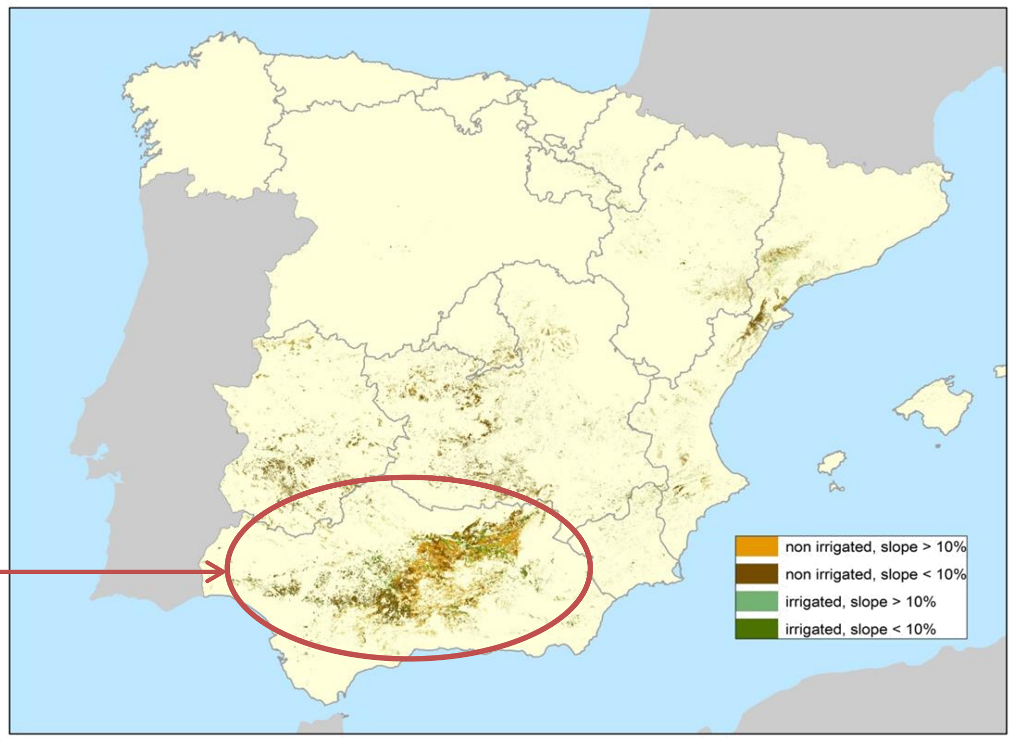
1. Introduction

- Currently, **Olive Tree Pruning** (OTP) biomass has attracted great interest as feedstock for biorefinery processes since it constitutes an abundant, cheap and available resource.
- It is produced mainly in **Andalusia region**, where 3.5 millions of tons of OTP are obtained per year.

Andalusia



1. Introduction

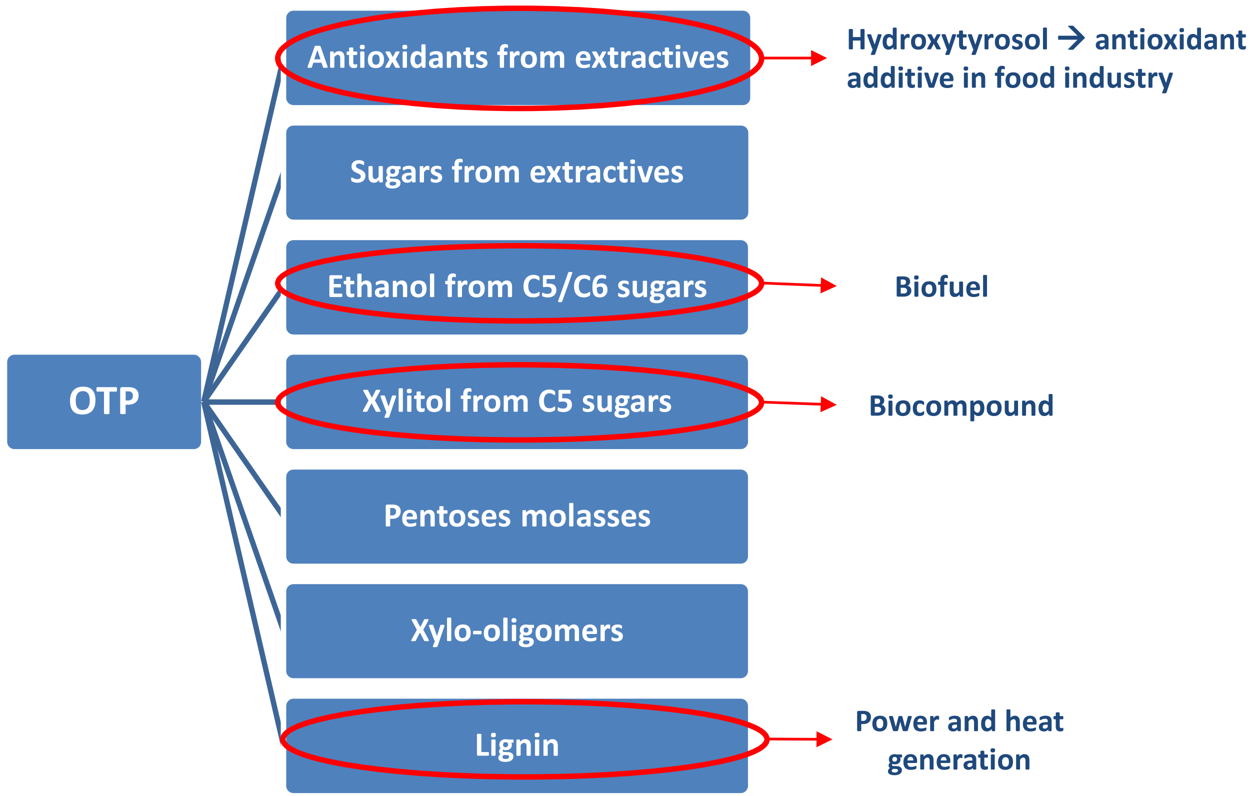
- Currently, OTP is burned and left on-site, which produces greenhouse gases and could led to diseases propagation.
- As an alternative, OTP could be uses as feedstock for a biorefinery process, producing bioproducts and biofuels.

Component	wt%
Extractives	24.5
Cellulose	23.1
Hemicellulose	16.7
Lignin	20.4
Acetyl	1.7
Ash	4.8
Undetermined	8.80

- **Antioxidants**
- **C5/C6 sugars**
- **Mannitol**

1. Introduction

POTENTIAL BIOPRODUCTS FROM OTP BIOMASS



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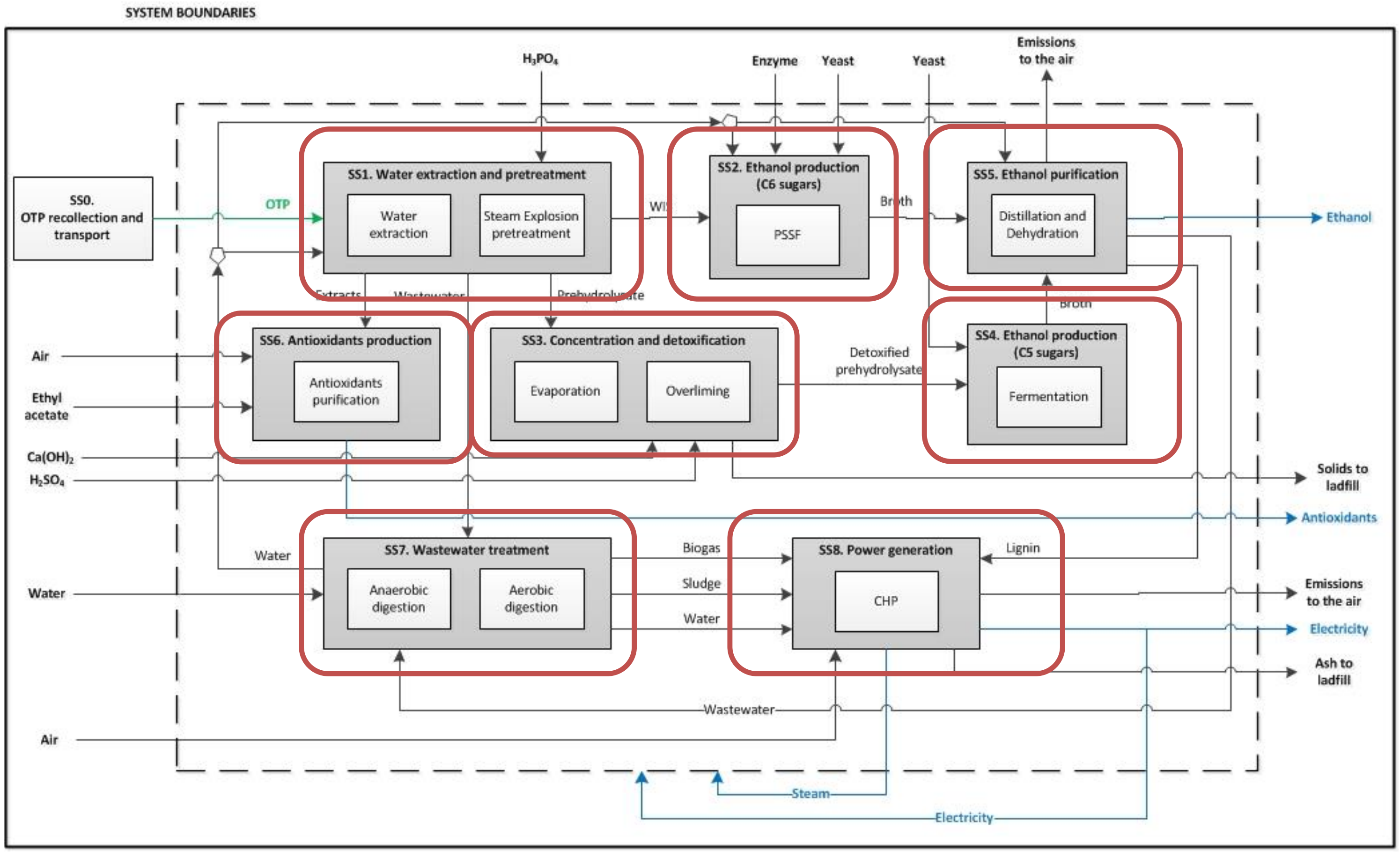
2. Cases study

OTP based biorefinery- Scenarios definiton

Case A

- Antioxidants + Ethanol + Heat&Power

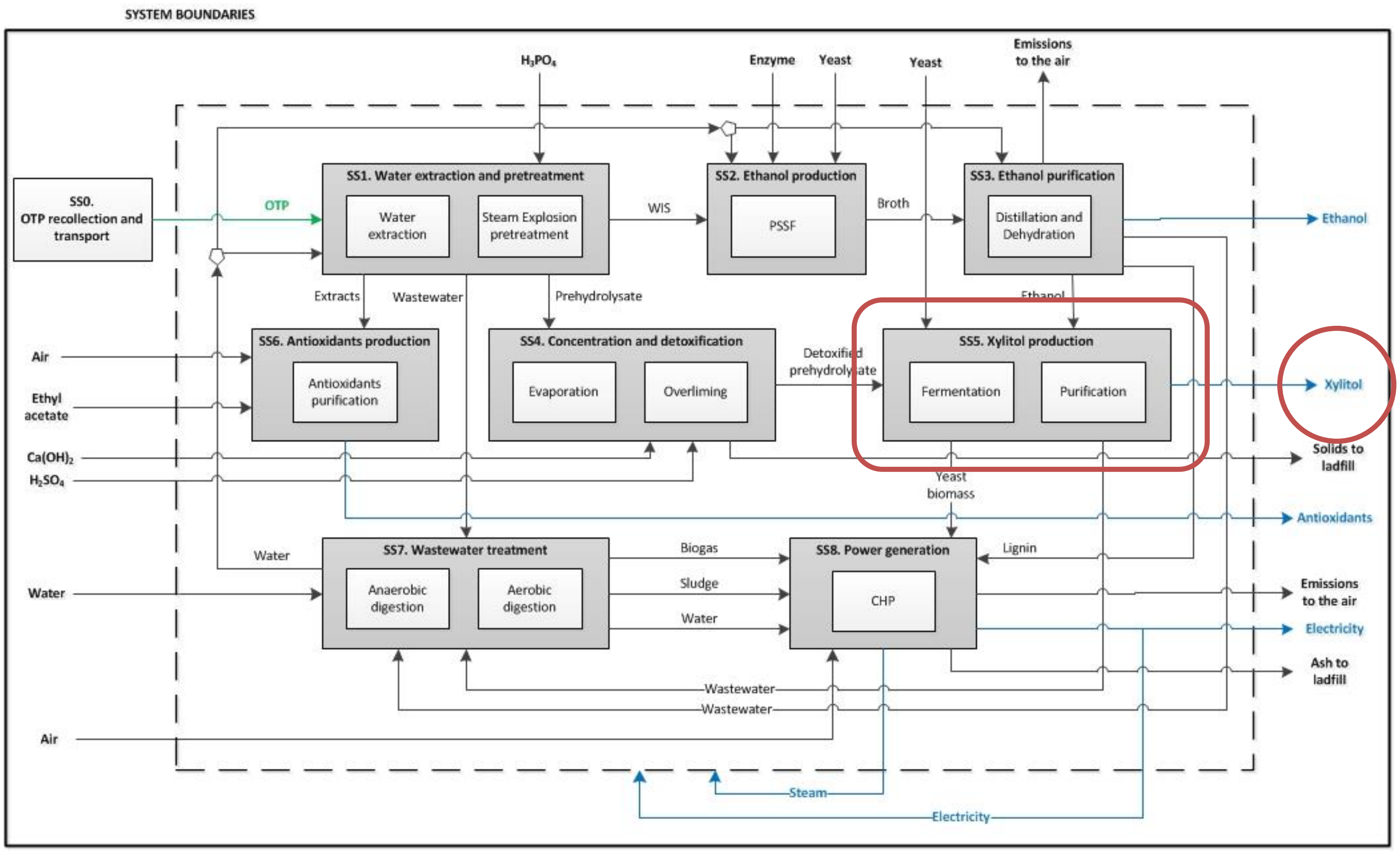


2. Cases study

OTP based biorefinery- Scenarios definiton

Case B

- Antioxidants + Ethanol + Xylitol + Heat&Power



3. Aspen simulation

OTP based biorefinery

- ✓ **Plant capacity: 40,000 tonne/year OTP.**
- ✓ **Biorefinery simulation in Aspen Plus.**
- ✓ **Thermodynamic model: Non-random two liquid (NRTL) and Hayden-O´Conell equation of state.**

PRODUCT	CASE A	CASE B	Units
Ethanol	159.6	107.5	L t^{-1} OTP
Xylitol	-	27.2	kg t^{-1} OTP
Antioxidants	43.2	43.2	kg t^{-1} OTP
Electricity	0.4	0.3	MWh t^{-1} OTP

4. Results

Economic analysis

- ✓ **Capital cost and operating cost: Aspen Economic Analyzer.**
- ✓ **Economic analysis was made for a 10-year period.**
- ✓ **Capital depreciation was calculated using the straigh-line method.**
- ✓ **Interest rate and income tax: 6% and 25%, respectively.**

Item	Case A	Case B
Capital cost		
Equipment cost (M€)	19.5	21.5
Total Investment cost (M€)	**43.2**	**47.0**
Operating cost		
Inputs (M€/year)	3.2	3.2
Utilities (M€/year)	1.3	1.5
Labor cost (M€/year)	1.8	1.8
Maintenance (M€/year)	1.3	1.4
Administration and insurance (M€/year)	0.3	0.3
Depreciation expense (M€/year)	4.3	4.7
Credit by electricity (M€/year)	**-1.2**	**-1.0**
Total operating cost (M€/year)	**11.0**	**11.9**

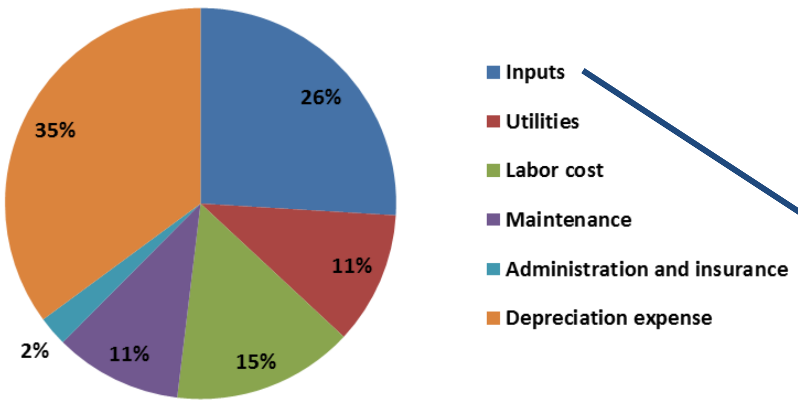
With Xylitol production→ 7.6 % increase in operating cost

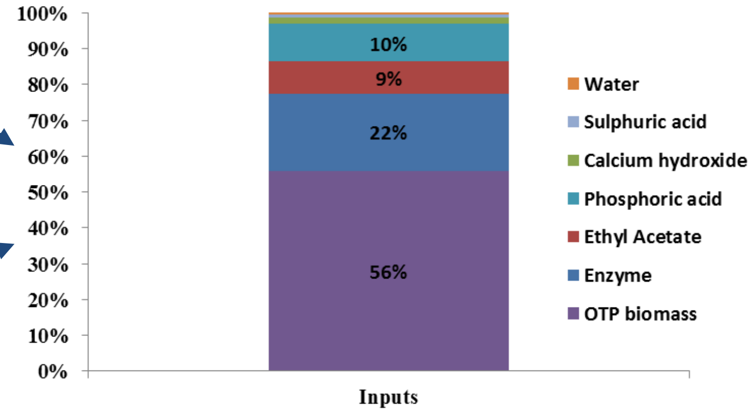
4. Results

Economic analysis

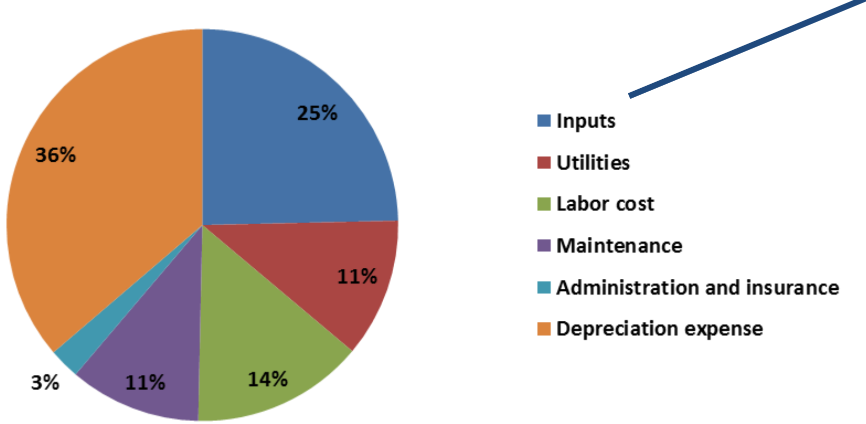
- ✓ **Operating cost contribution**

Case A





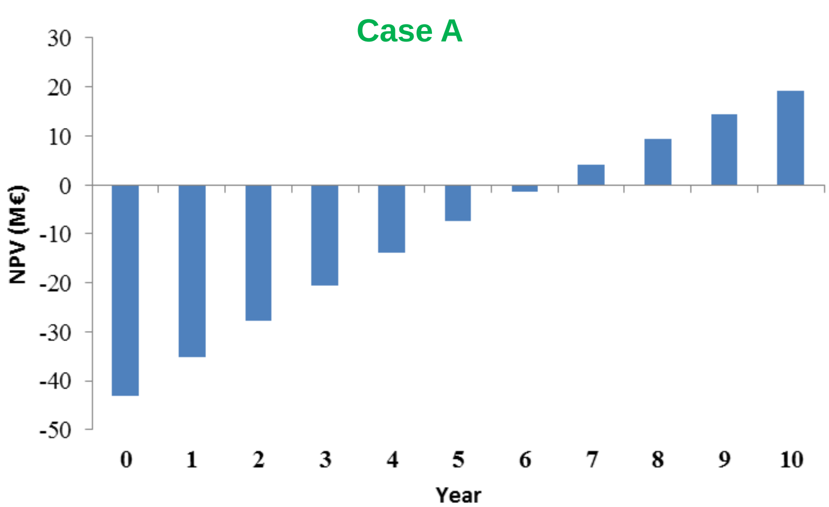
Case B

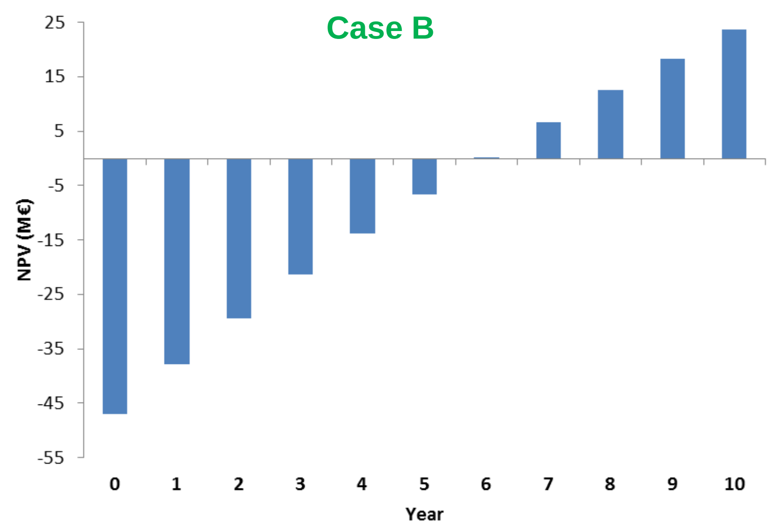


4. Results

Economic analysis

✓ **Net Present Value and Payback period**



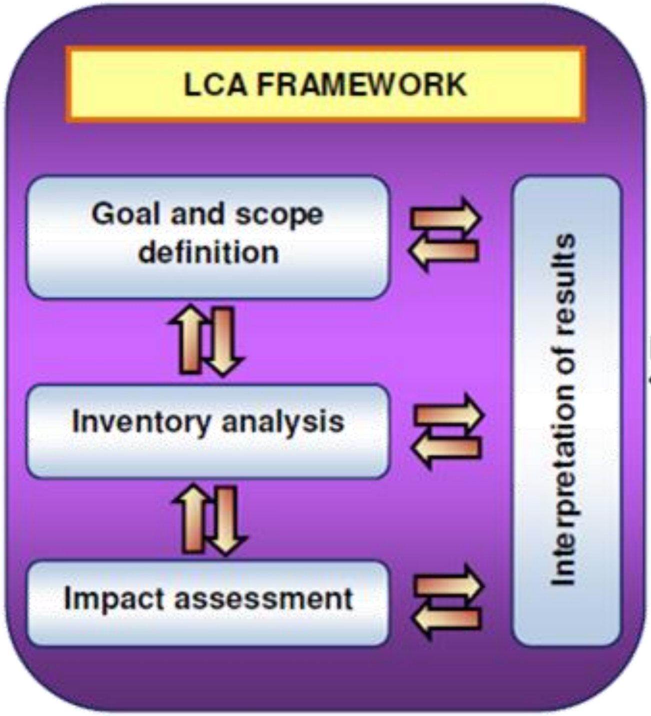


NPV: 19.2 M€
Payback: 7 year

NPV: 23.6 M€
Payback: 6 yea

4. Results
Life cycle assessment

- ✓ **Life cycle assessment**: **technique for assessing the environmental aspects and potential impacts associated with a product by compiling an inventory of relevant inputs and outputs of a product system, evaluating the potential environmental impacts associated with those inputs and outputs and interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study.**



ISO 14040:2006
ISO 14044:2006

4. Results

Life cycle assessment

- ✓ **Functional unit : 1 t of ethanol at plant (99.9 % purity).**
- ✓ **"Cradle-to-gate" approach: from OTP obtainment to the supply of the products at plant.**
- ✓ **Key inventory data were taken from the simulation of the processes in Aspen Plus.**
- ✓ **Inventory data for background processes were taken from ecoinvent database.**

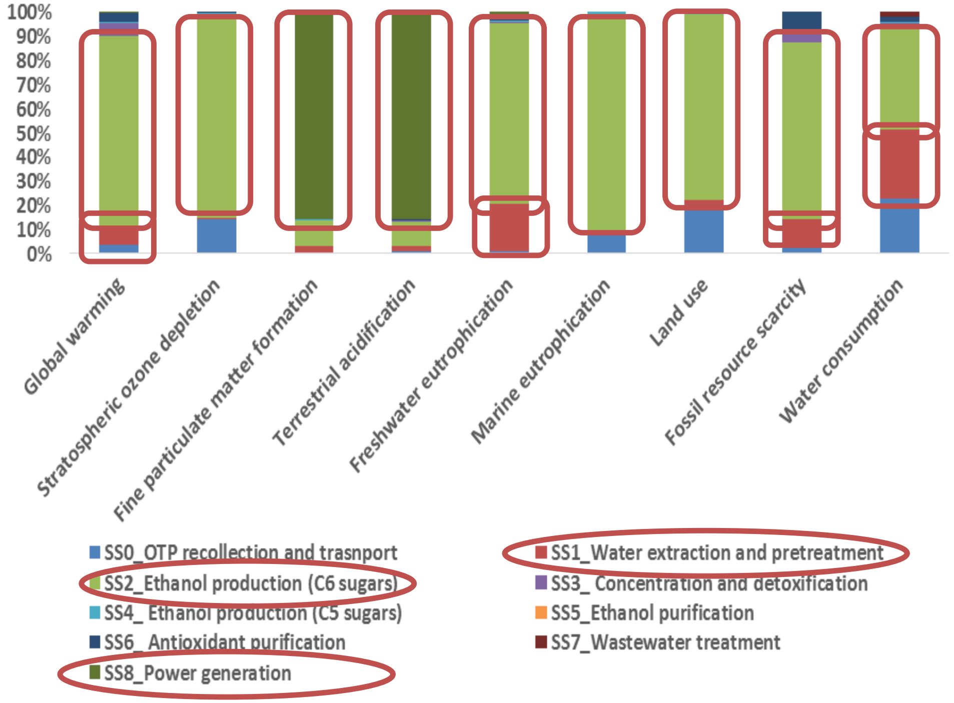
Environmental profile of the biorefinery systems (values per FU)

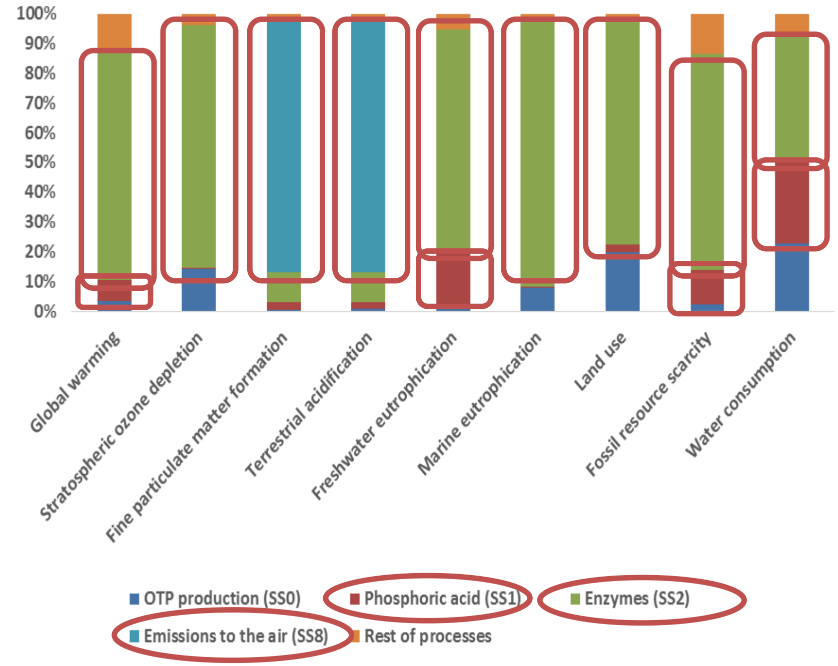
Impact category	Case A	Case B
Global warming (kg CO_2 eq)	3188.76	4727.06
Stratospheric ozone depletion (kg CFC11 eq)	0.01	0.02
Fine particulate matter formation (kg PM2.5 eq)	42.59	72.4
Terrestrial acidification (kg SO_2 eq)	139.63	237.3
Freshwater eutrophication (kg P eq)	1.67	2.5
Marine eutrophication (kg N eq)	3.36	5,0
Land use (m^2a crop eq)	2645.82	3924.1
Fossil resource scarcity (kg oil eq)	811.01	1203.4
Water consumption (m^3)	94.02	139.5

4. Results

Environmental characterization

Case A





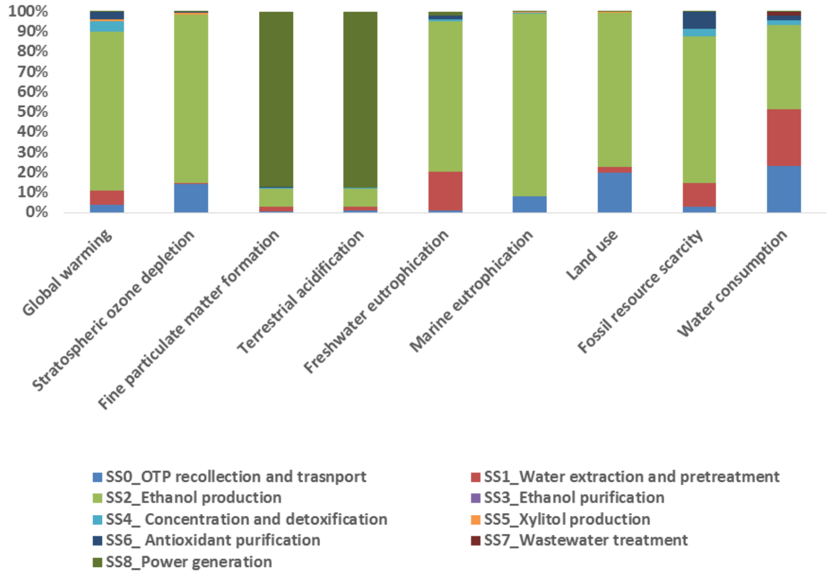
Biorefinery areas contributions to the potential impacts

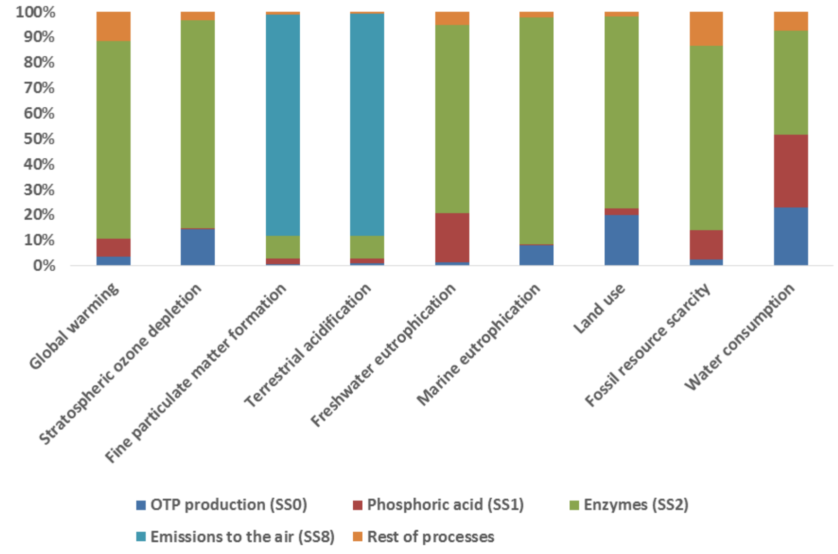
Specific process contribution to the potential impacts

4. Results

Environmental characterization

Case B





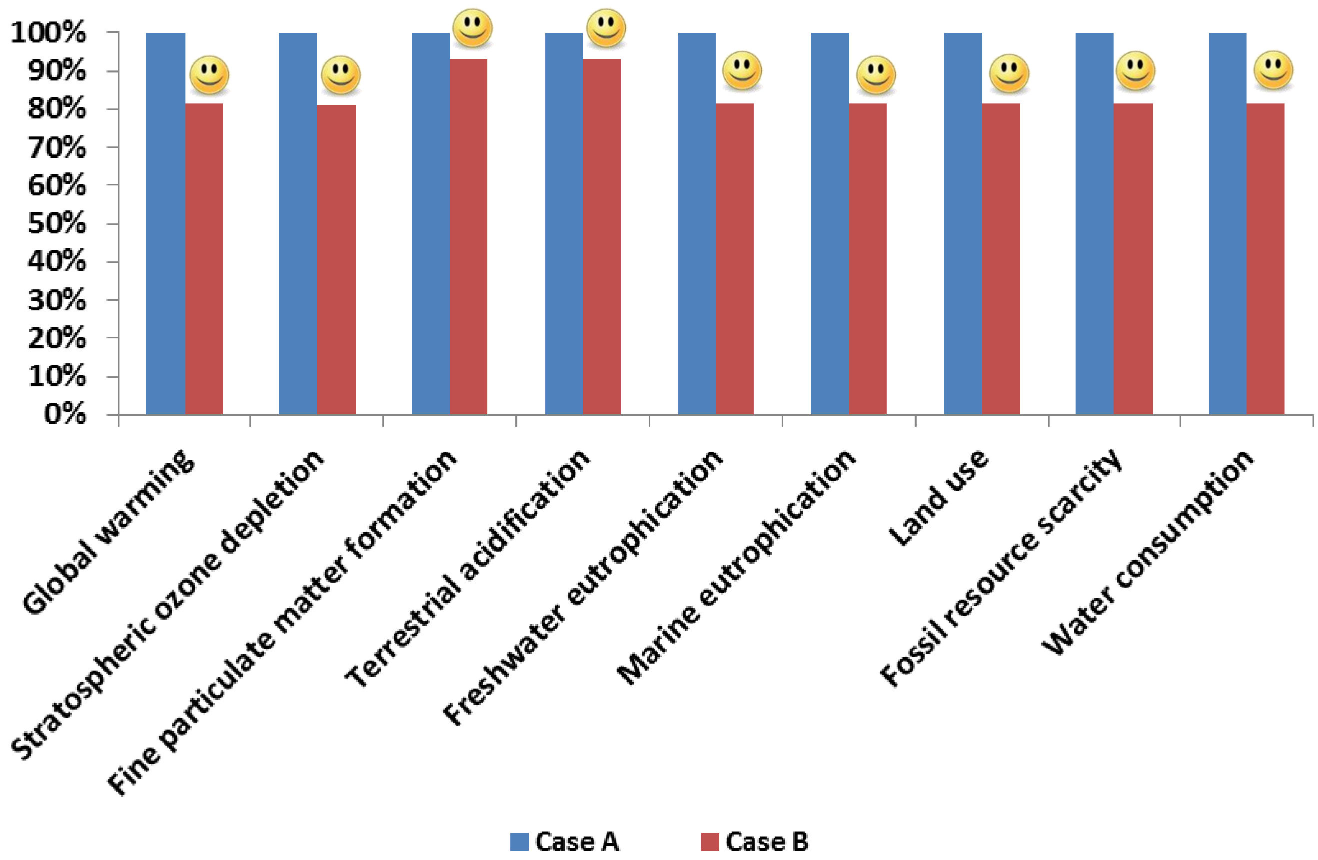
Subsystems contribution to the potential impacts

Process contribution to the potential impacts

4. Results

Comparison

✓ **Functional unit : 1 € of profits.**



5. Conclusions

- ✓ Olive Tree Pruning (OTP) biomass is a **promising feedstock** for biorefinery processes since it constitutes an abundant, cheap and available resource that can be used for production of biofuels (ethanol) and valuable compounds (antioxidants and sugars).
- ✓ These results demonstrate the technical feasibility to obtain bioethanol alongside bioproducts (antioxidants and xylitol) at small scale.
- ✓ The **depreciation expense and inputs cost of OTP biomass** were identified as the main contributors to the operating cost. Enzyme also contributes significantly.
- ✓ The **economic analysis** of the biorefinery systems show a positive Net Present Value (NPV) for the both cases, with better results when xylitol is also produced.
- ✓ The **LCA study shows** that the enzyme production dominates most of the impact categories except in the categories of fine particle matter formation and terrestrial acidification, which are dominated by the emissions to the air.
- ✓ **In terms of 1 € of profits**, better environmental behaviour is obtained when xylitol is also produced

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