Project SMIBIO

*DEVELOPMENT OF **FLEXIBLE SMALL-SCALE INTEGRATED BIOREFINERIES** TO PRODUCE AN OPTIMAL RANGE OF BIOPRODUCTS FROM A VARIETY OF RURAL AGRICULTURAL AND AGRO-INDUSTRIAL RESIDUES/WASTES WITH A MINIMUM CONSUMPTION OF FOSSIL ENERGY*

Francisco Gírio

SMIBIO Coordinator
Head of Bioenergy Unit
LNEG, Portugal

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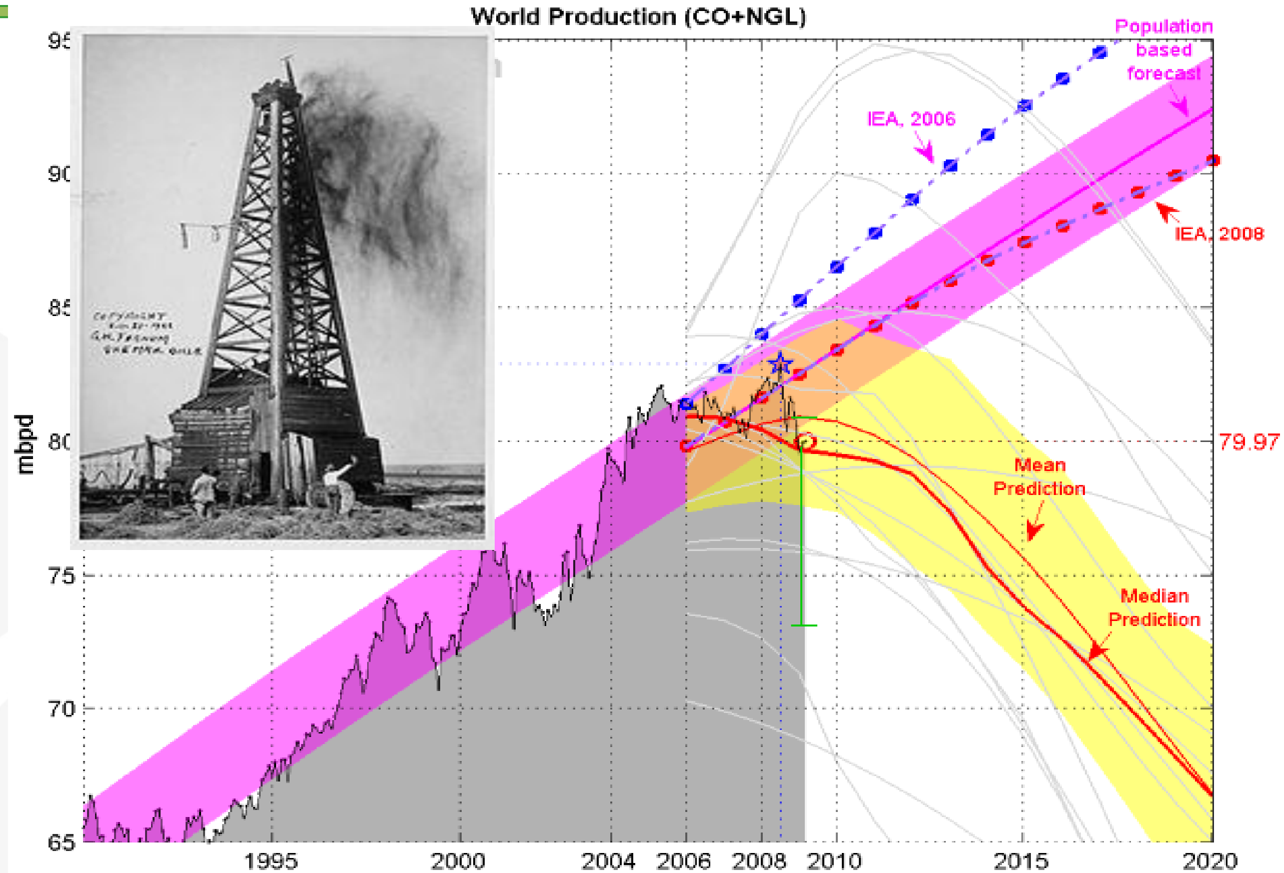
Did crude oil reach a production peak?

23.10.2003

Break News: Saudi Arabia sees End of Oil Age coming and opens valves on the carbon bubble
January 22, 2015 ("EnergyPost")

However,
This is not the point…!



World oil production (EIA Monthly) for crude oil + NGL. *<u>The median forecast is calculated from 15 models that are predicting a peak before 2020</u> (Bakhtiari, Smith, Staniford, Loglets, Shock model, GBM, ASPO-[70,58,45], Robelius Low/High, HSM,Duncan&Youngquist). 95% of the predictions sees a production peak between 2008 and 2010 at 77.5 - 85.0 mbpd (The 95% forecast variability area in yellow is computed using a bootstrap technique).*
The magenta area is the 95% confidence interval for the population-based model.

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The point is (I)….

Climate Change

Norway
Source: National Geographic

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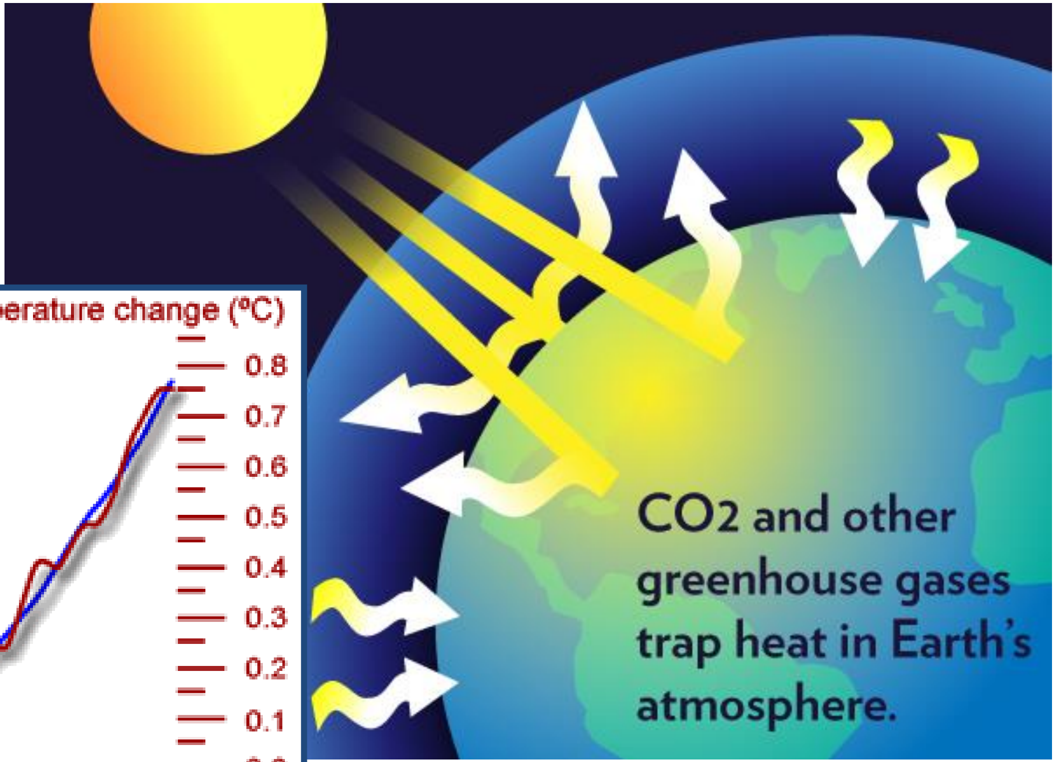
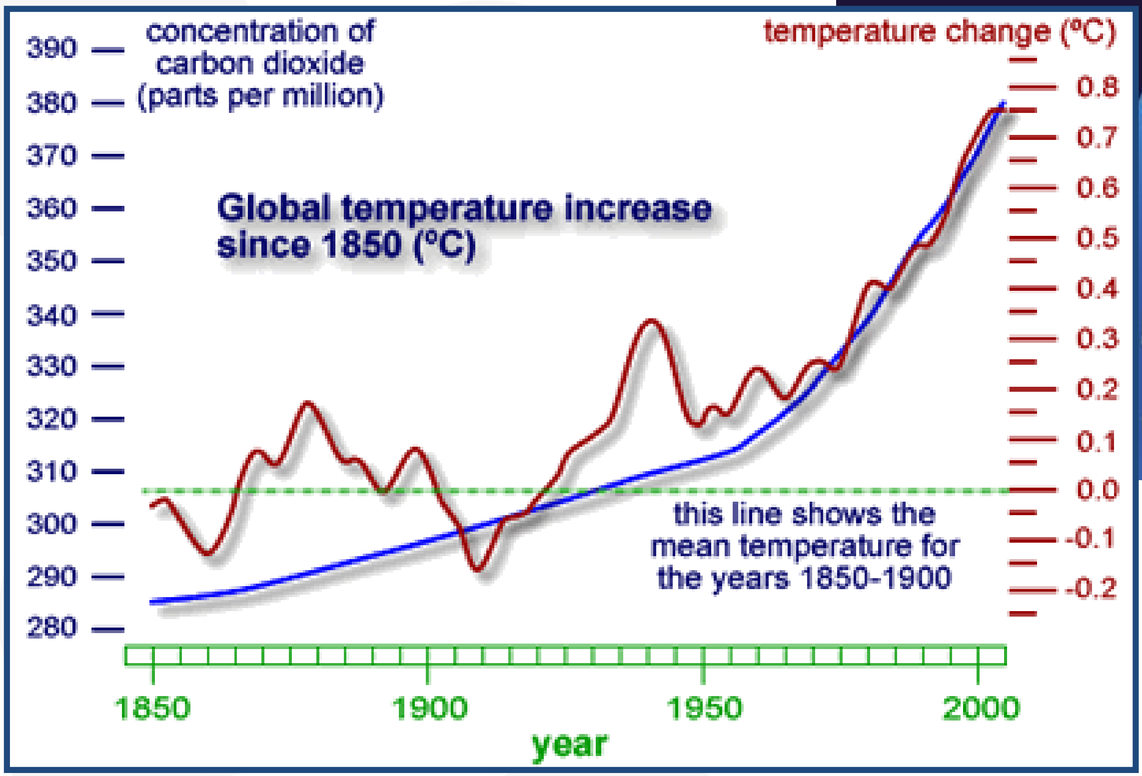
The point is (II)….

Global Warming





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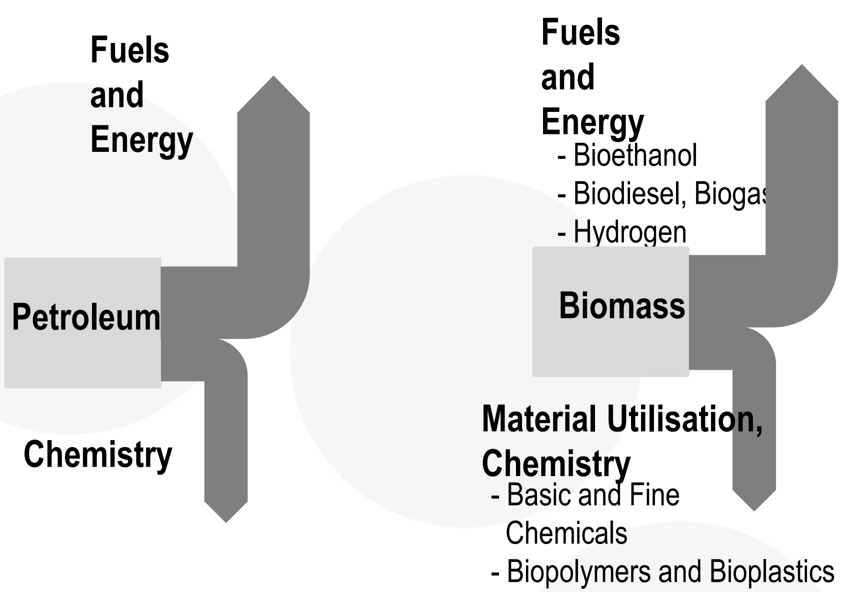
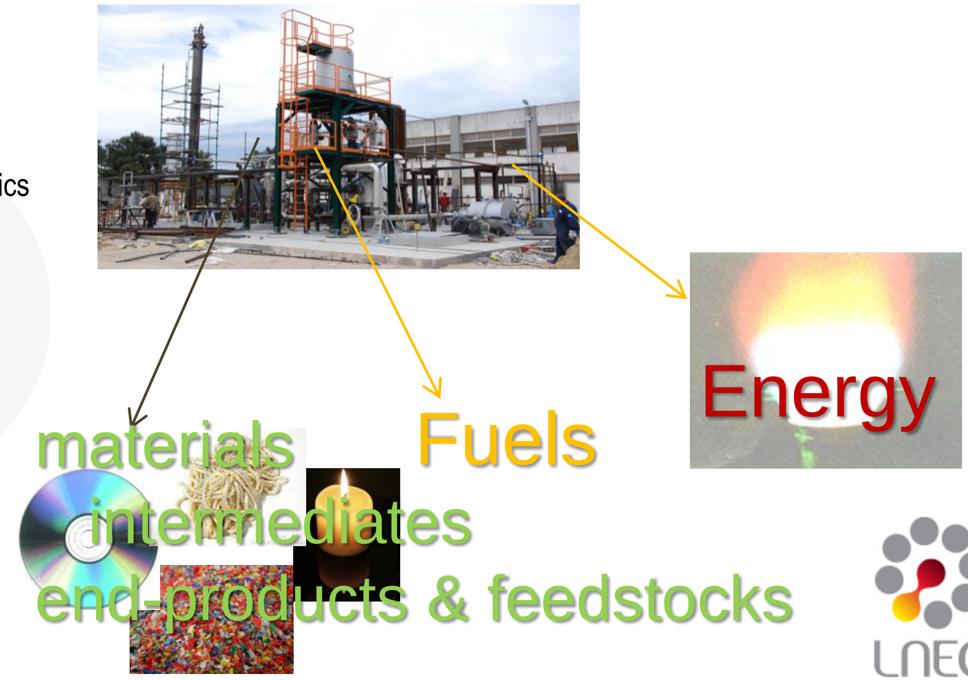
Biorefinery Concept



Refinery   Biorefinery

Similar to an oil refinery, a biorefinery is an industrial plant that converts Renewable Resources - BIOMASS (instead of fossil petroleum) into bio-based products, fuels and energy.



Bio-based products:

- Bio-based materials
- Bio-based chemicals
- Biofuels
- Bioenergy

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2. BIOREFINERIES KEY-CHALLENGES FOR NEXT DECADE

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2. BIOREFINERIES KEY-CHALLENGES FOR NEXT DECADE

Feedstock

Non-food biomass supply chain:
Sustainable feedstock (at large quantities?)

Competition for lignocellulosic biomass uses

Lignocellulosic Biomass as a world commodity

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Technology

Lignocellulose recalcitrance

How to better integrate different technologies ?

Dedicated versus mixed 1G/2G biorefineries

Materials

Multi-product Biorrefinery

Balance between energetic products and bioproducts

Removing the economic barriers
(eg. high CaPEX, high OpEX, high risk)

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Market uptake

Consumer acceptance

Demo and flagship Units

Trade barriers (subsidies, etc)

Biofuels vs.
E-vehicle, FCV, Hybrids, etc

LNEG

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The aim of SMIBIO is to study the **technical-economic and environmental viability of small scale integrated biorefinery units** capable of processing different kinds of biomass produced in short radius catchments of rural and small urban areas, both in Europe and in LAC countries.

- How we do this? ……**Local Feedstocks/Wastes = Local Solutions!**
- By modelling the best technological solutions **under proper and real conditions**, for different rural/urban regions (at least two in EU countries and two in LAC countries), **after considering optimal processing of local biomass in each selected region**.
- The project is developing **appropriate tools and methods** to properly assess the technologies and optimize overall energy efficiency, environmental (LCA), economic (IRR, NPV and production costs), and social impacts (improvement in living conditions, job creation and new opportunities for rural development identification) **for any small-scale integrated biorefinery**.
- Sustainability impacts will be assessed and validated for the small-scale biorefineries.

LNEG

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SMIBIO

SMall-scale Integrated BIOrefineries : Consortium

WP1. Biorefinery Conceptual Design and Selection of Business Case Studies. (Month 1-9)
WP Leader: CIEMAT
Participants: All Partners + Associate Partners +Stakeholders

WP2. Process Simulation of Sugar and Biogas Platforms. (Month 6-30)
WP Leader: UNC
Participants: LNEG, CIEMAT, PUCV, UNAM

WP3. Research for Process Integration and Optimization of Both Platforms. (Month 1-30)
WP Leader: LNEG
Participants: PUCV, CIEMAT, IBt-UNAM

WP4. Process Integration and Optimization of Both Platforms. (Month 6-36)
WP Leader: UNC
Participants: PUCV, LNEG, WIP, UNC, CIEMAT, IBt-UNAM

WP5. Model Application to Rural Areas. Workshops & Dissemination. (Month 1-36)
WP Leader: WIP
Participants: WIP, UNC, LNEG, CIEMAT, IBt-UNAM, Assoc. Partners and Stakeholders

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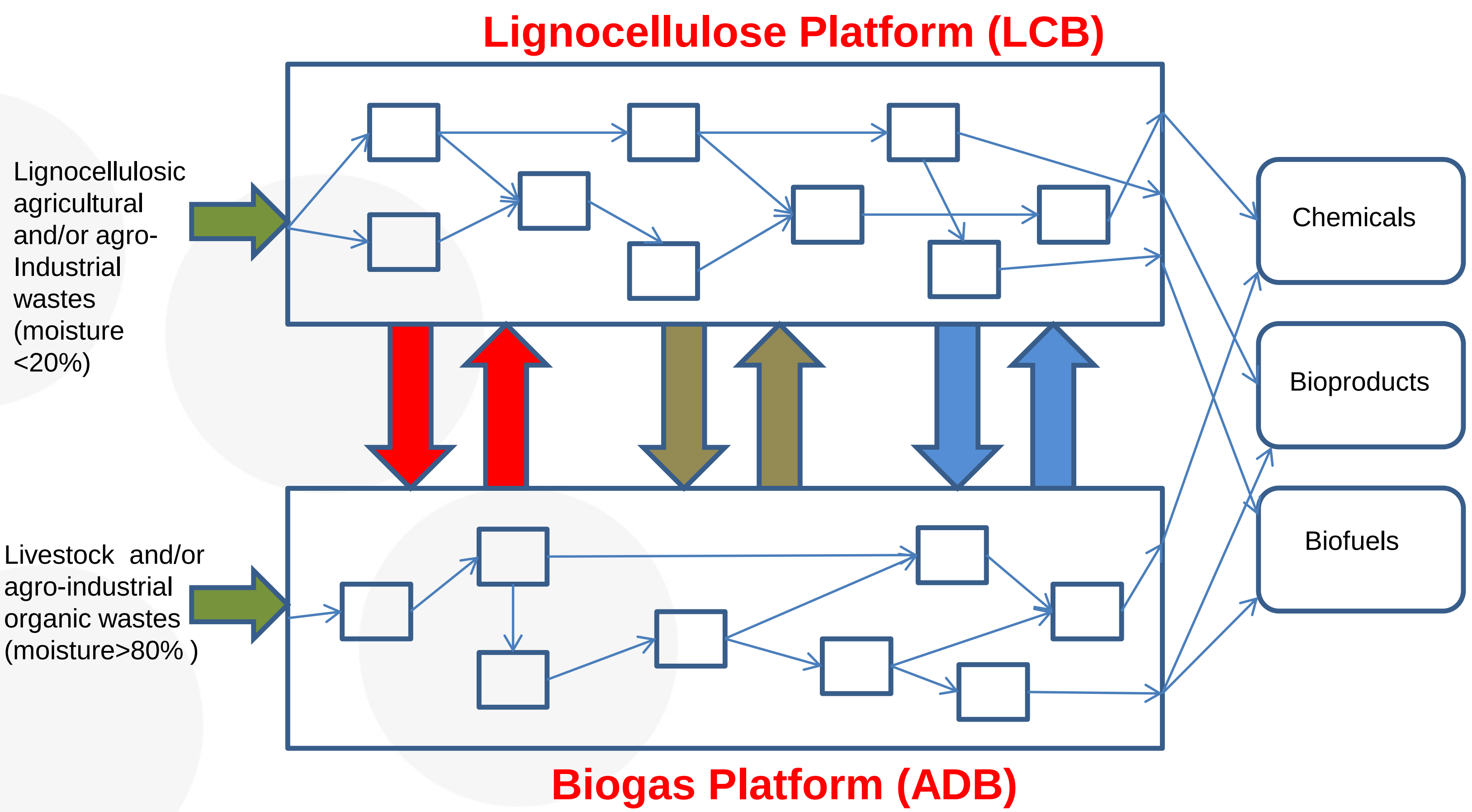
SMIBIO

SMall-scale Integrated BIOrefineries : Two Platform Simplified Model



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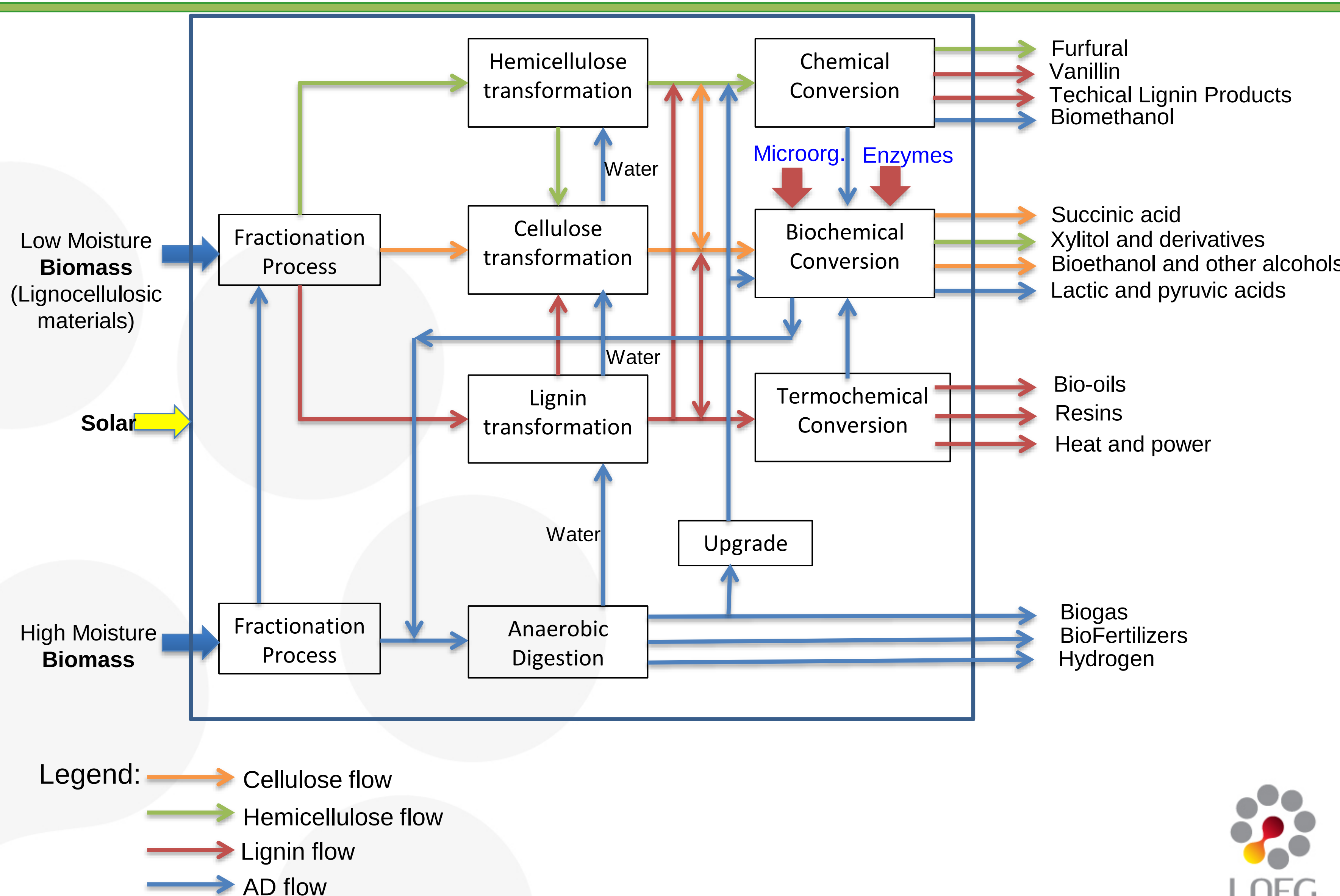
SMall-scale Integrated BIOrefineries: The Concept



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SMALL SCALE BIOREFINERIES!

Is the key for most rural areas in EU and LAC countries...however can them be feasible and sustainable?

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HEURISTIC ANALYSIS Local (selected) Feedstocks

Dry Biomass (LCB Platform)

Corn Stover

Data from CADOVA (SMIBIO stakeholder partner)
113,000 ton/year available (in a 50 km radius around Chamusca region)
160,000 ton/year (in a 100 km radius around Chamusca region)

Feedstock properties

Item	Value	Units
Amount (produced)	100 000	ton/year
% Glucan	40.83	%
% Xylan	23.48	%
% Arabinan	3.06	%
% Lignin	16.91	%
% Others*	15.72	%

* Not relevant for the mass balances considered in this study

Concerning the accessibility to the feedstocks (logistics, annual production, competitors, etc.) around 30% of the total amount is considered to be accessible to be used within the biorefinery

Minimum available corn stover: **30,000 ton/year**
Theoretical max. Available: **113,000 ton/year**

Wet Biomass (ADB Platform)

Swine Manure

Data from STRADALUX (SMIBIO stakeholder partner)
303 m^3/day – 110,000 m^3/year of effluent

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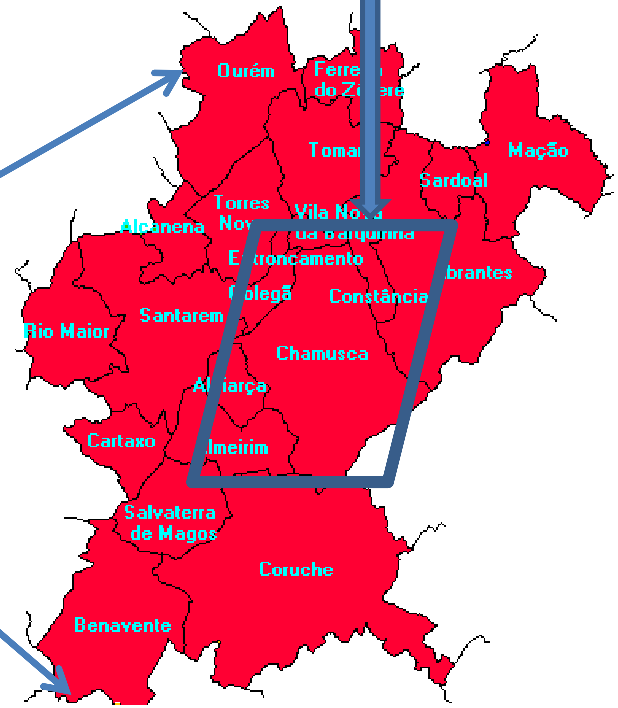
HEURISTIC ANALYSIS Selected Geographical Area

Province of Santarem (about 80 kms North of Lisbon)

Chamusca region (50 km radius)



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HEURISTIC ANALYSIS Biorefinery Design

SCENARIO A — **Ethanol (C6 sugars) + Pentose Molasses + Lignin (CHP)**

Pentose molasses for animal feed; local costumers

SCENARIO A' — **Ethanol + Xylooligosaccharides (XOS) + Lignin (CHP)**

XOS to be used as food or feed additive (1% wt.); e.g. prebiotic; World costumers

SCENARIO B — **Ethanol (C5/C6 sugars) + Lignin (CHP)**

Ethanol from C5/C6 sugars; local costumers

SCENARIO C — **Ethanol (C6 sugars)+ Xylitol (XOH) + Lignin (CHP)**

Xylitol production from C5 sugars; World costumers

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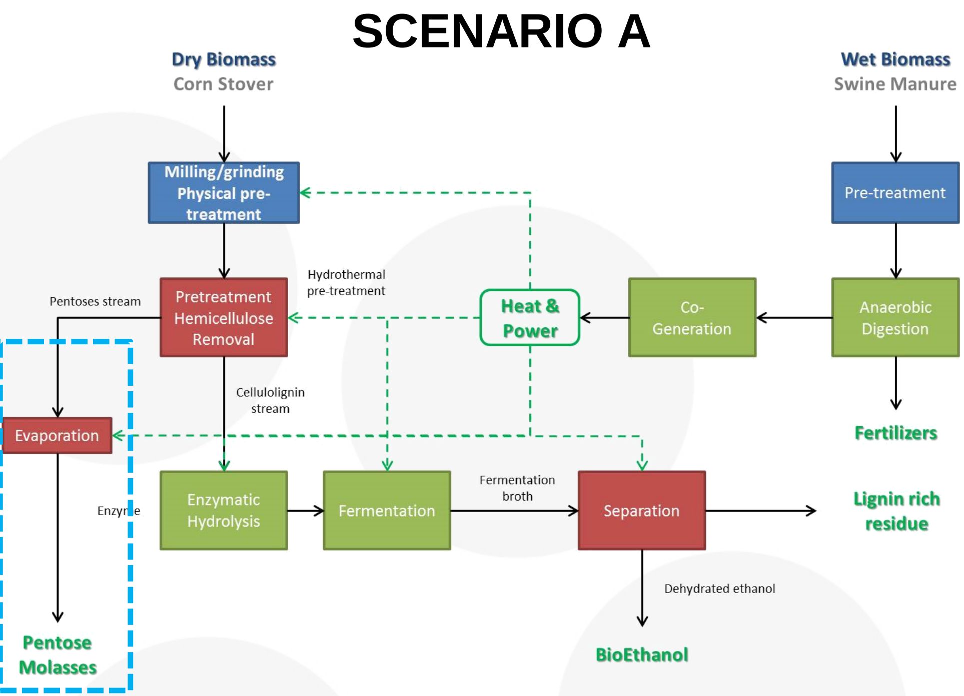
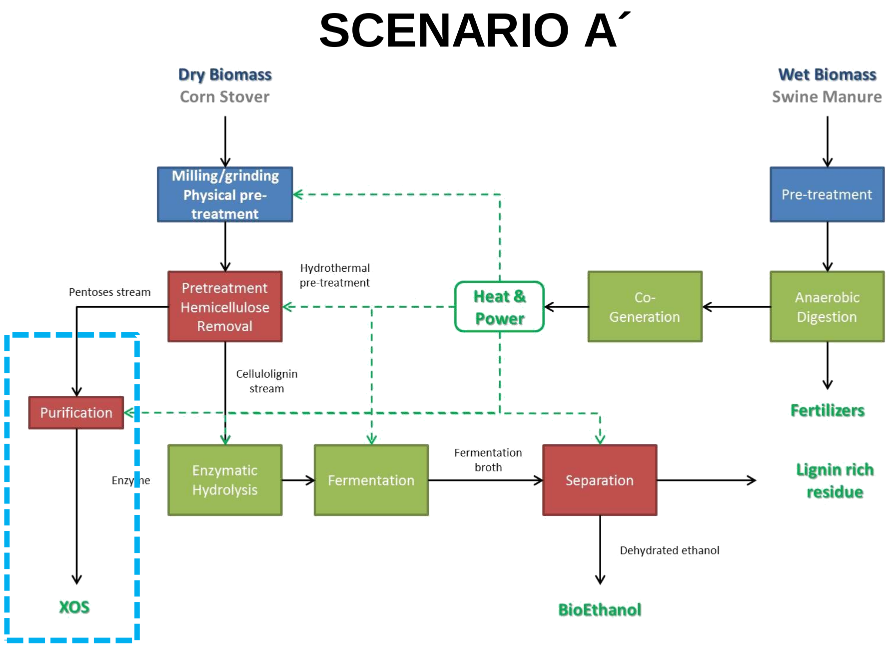
SCENARIO A EtOH + C5 Molasses + Lignin (CHP)

SCENARIO A’ Ethanol + XOS + Lignin (CHP)





- Fermentation of C6 sugars only
- **Evaporation as the concentration process to obtain C5 molasses (mainly XOS) – for feed**
- Separation also includes distillation/dehydration
- Lignin residue is obtained after distillation

- Fermentation of C6 sugars only
- **Purification step (UF/NF membranes) of XOS – for human food**
- Separation also includes distillation/dehydration
- Lignin residue is obtained after distillation

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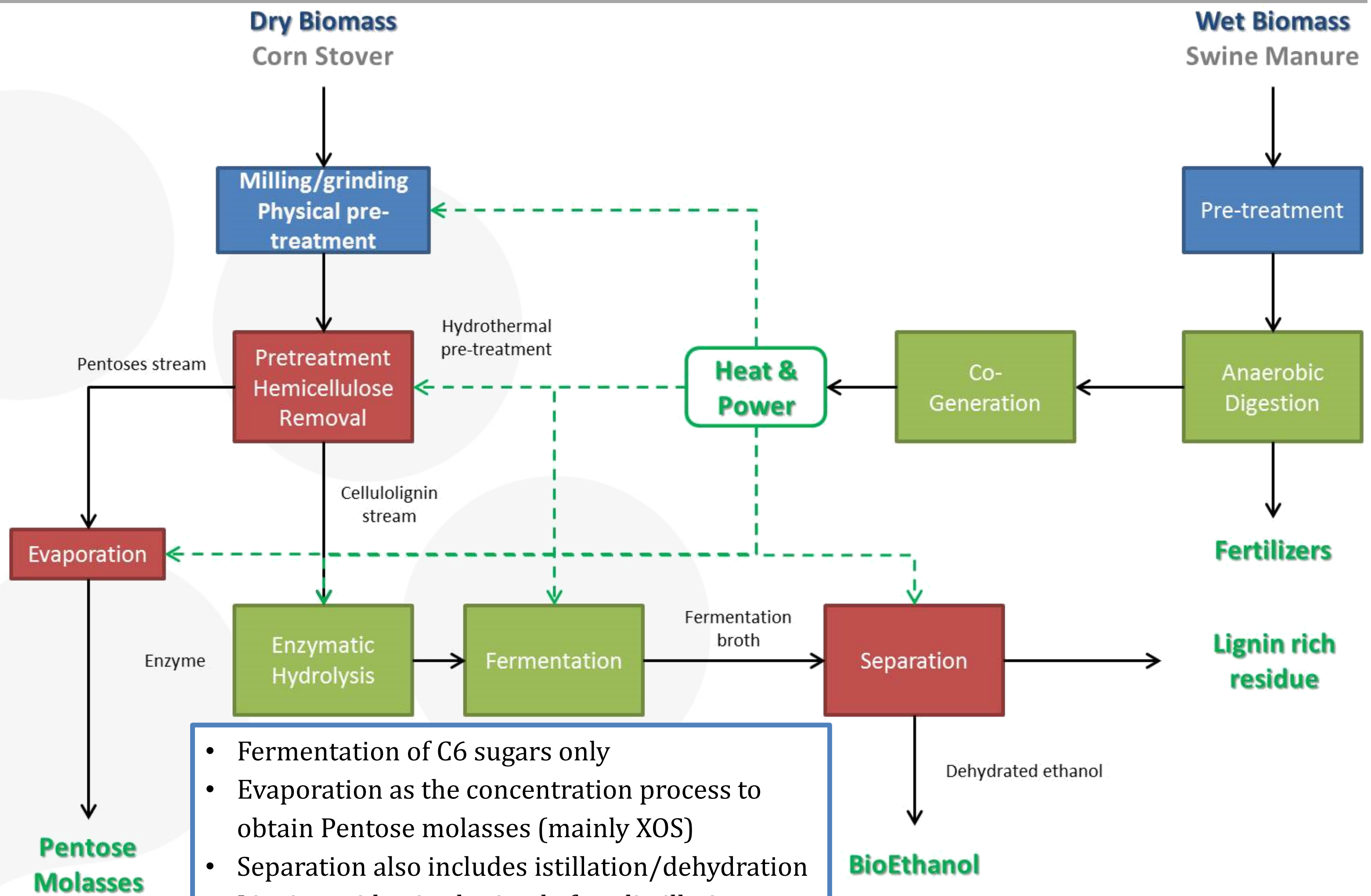
SCENARIO A Ethanol + Pentose Molasses + Lignin (CHP)



- Fermentation of C6 sugars only
- Evaporation as the concentration process to obtain Pentose molasses (mainly XOS)
- Separation also includes istillation/dehydration
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HEURISTIC ANALYSIS Preliminary Mass Balance

SCENARIO A Ethanol + Pentose Molasses + Lignin (CHP)

Scenario A	Technologies / Unit Operations								
	Milling	Hemicellulose Removal	Enzymatic Hydrolysis	Fermentation	Evaporation	Distillation	Pre-Treatment	AD	Co-Generation
Matureness Level	3	2	2	3	2	3	3	3	3

	Production (ton/yr)		
Feedstock (ton/yr)	**Ethanol**	**Lignin derivatives**	**Pentose Molasses**
30,000	4,475	6,802	6,002
40,000	5,967	9,070	8,003
50,000	7,459	11,337	10,004
60,000	8,951	13,604	12,004
70,000	10,442	15,872	14,005
80,000	11,934	18,139	16,006
90,000	13,426	20,407	18,006
100,000	14,918	22,674	20,007

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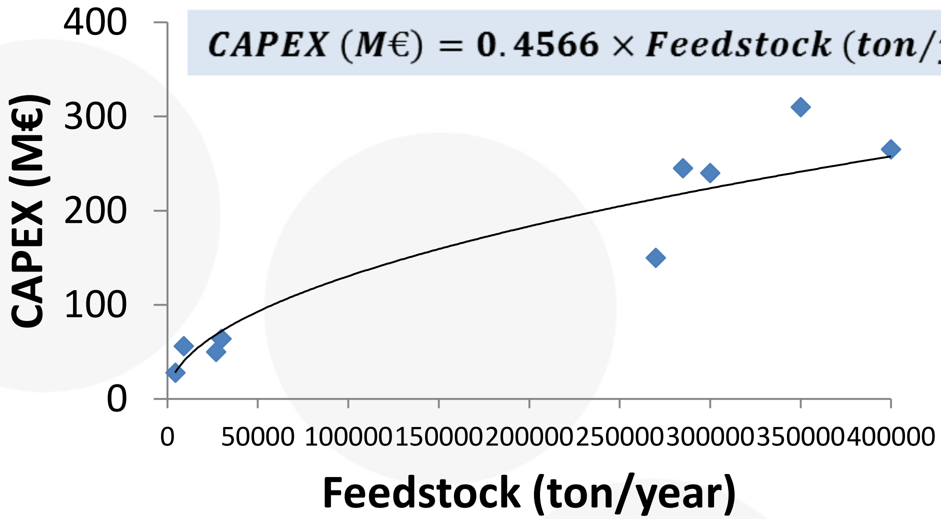
HEURISTIC ANALYSIS Preliminary Economic Analysis

$$CAPEX\ (M€) = 0.4566 \times Feedstock\ (ton/year)^{0.4912}$$



OPEX

SCENARIO A EtOH + C5 Molasses + Lignin

	Cost	Units
1) Feedstock		
Corn Stover	45	€/ton
Enzymes	152	€/ton EtOH
2) Operating Costs		
Distillation	65	€/ton
Steam (Pretreat./Evapor.)	10	€/ton
3) Labour		
Personnel costs	2500	€/month
# workers	20	

Market Prices	€/ton
Feedstock cost	45
Ethanol	600
Lignin	45
Pentose Molasses	135
XOS	3,500
XOH	3,600

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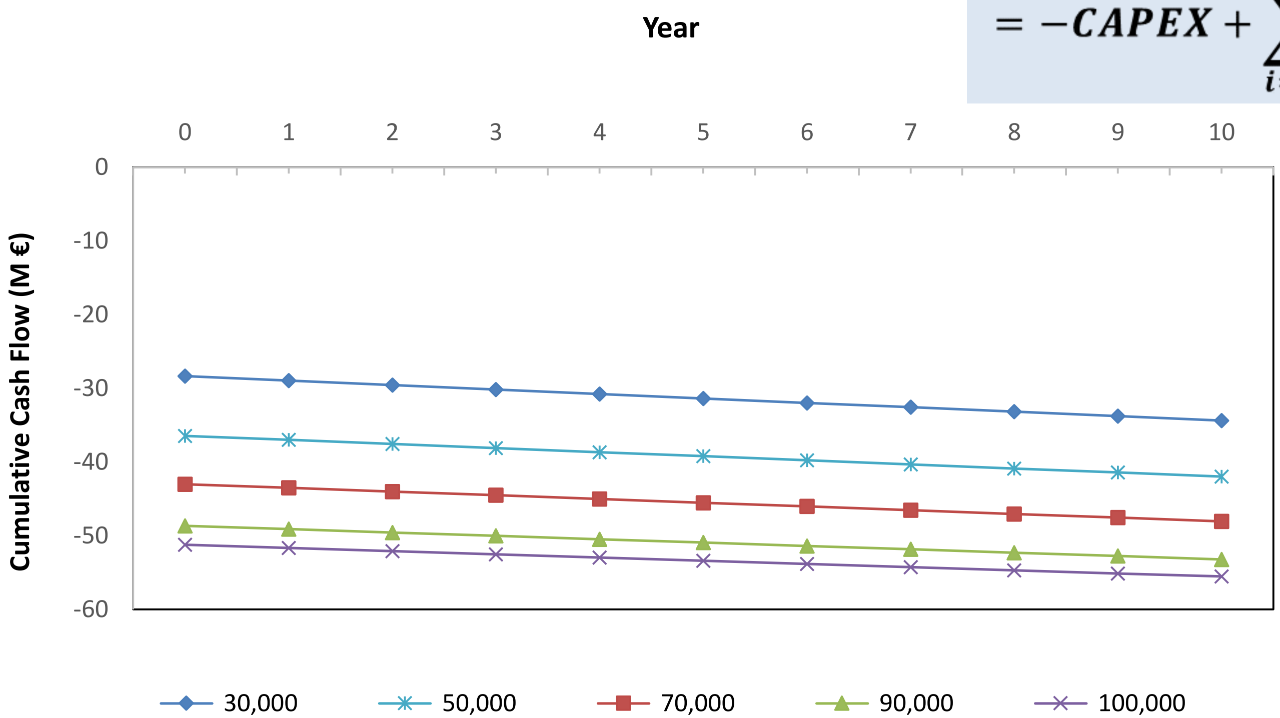
Cash Flow

SCENARIO A EtOH + Molasses + Lignin

$$\textit{Cumulative Cash Flow}\ (€) = -CAPEX + \sum_{i=1}^{n}(Sales - OPEX)$$



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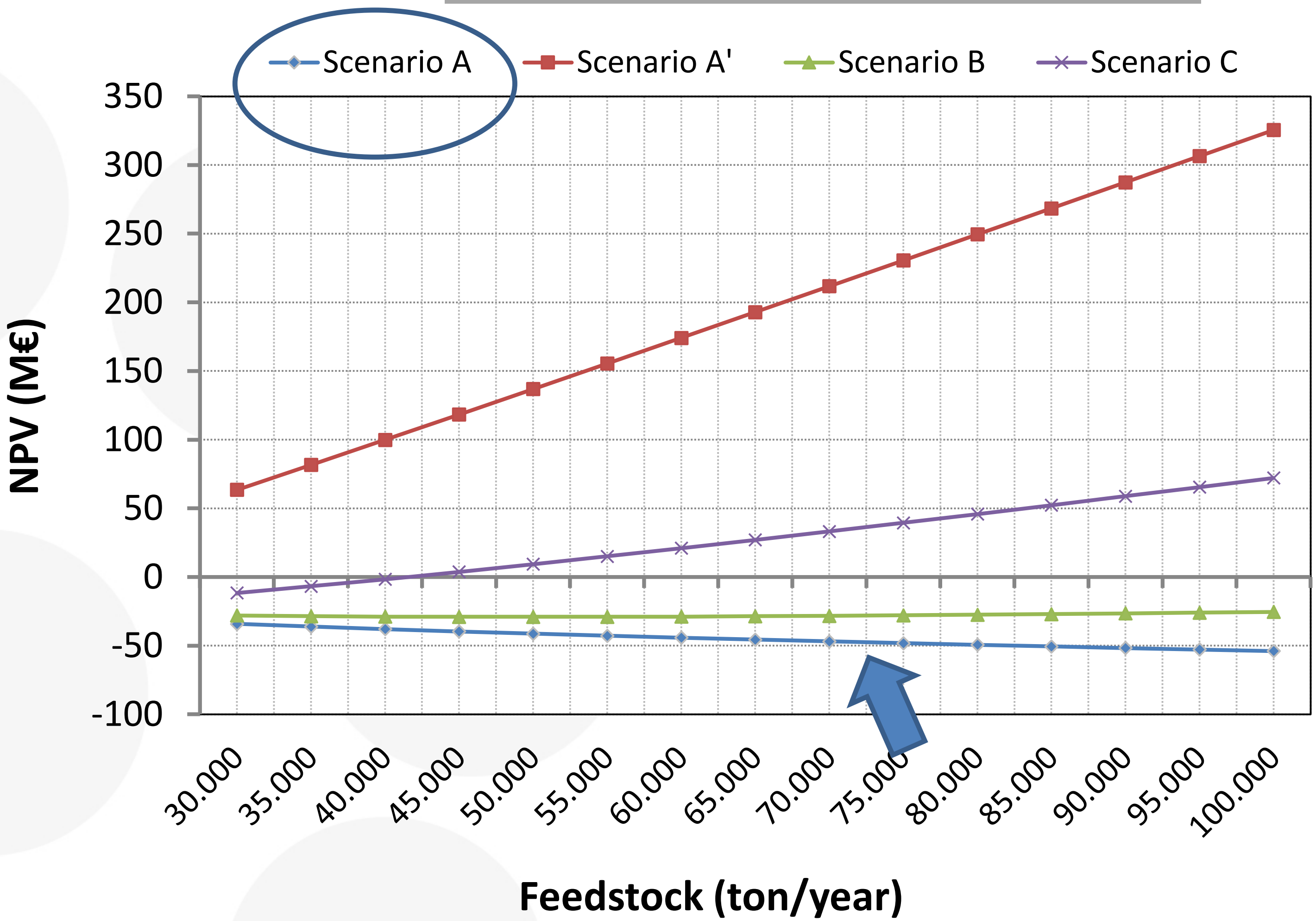
Net Present Value vs. Scale

SCENARIO A EtOH + Molasses + Lignin



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HEURISTIC ANALYSIS Conclusions for SCENARIO A

- **Not viable**
- Viable if lignin (valorized) is sold at higher prices than 0.90-1.70 €/kg (PBP – 5 yrs)
- Ethanol Production: 15,540 – 51,500 L/day
- Ethanol Production Cost: 0.77 – 0.85 €/L

LNEG

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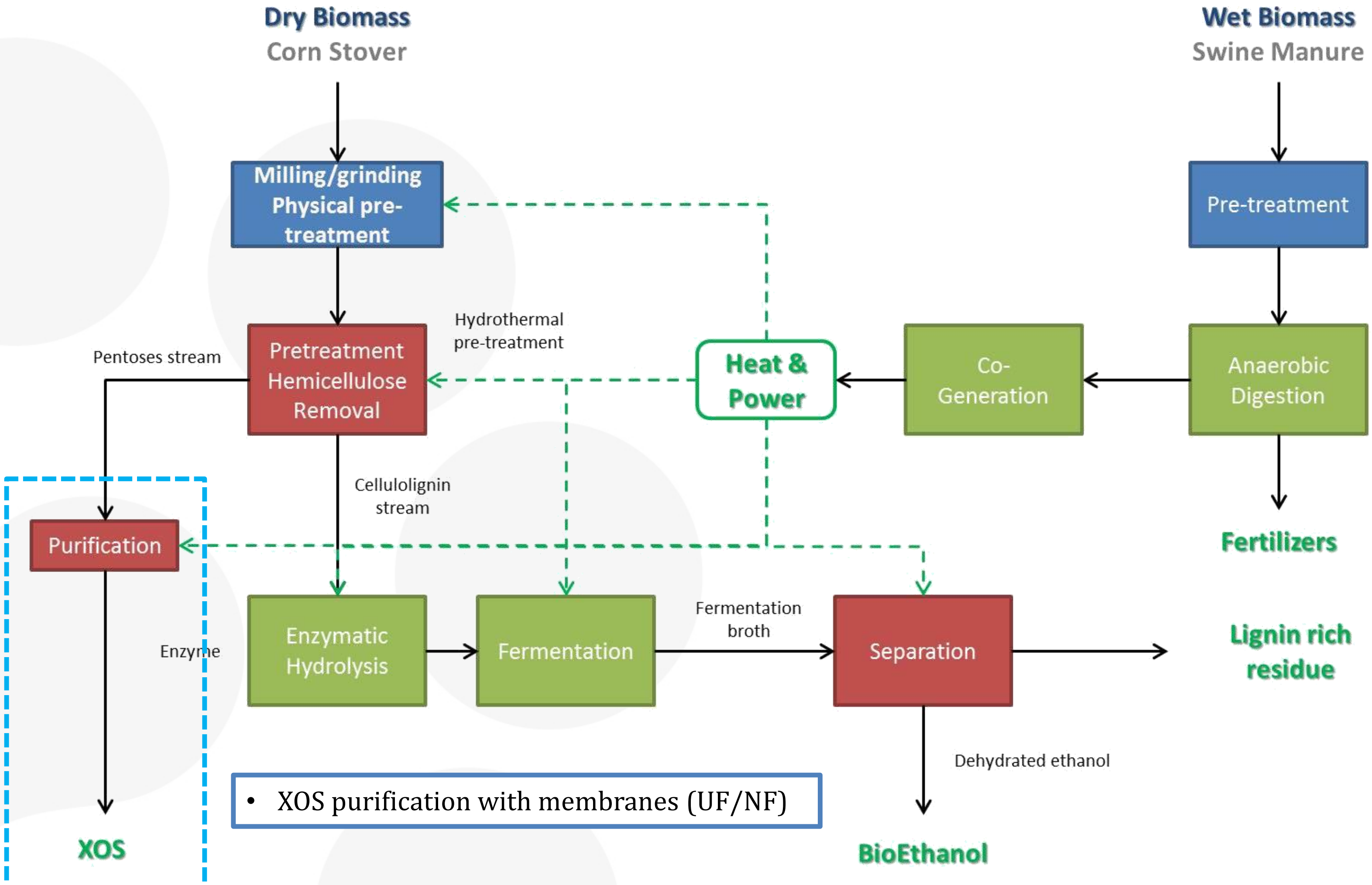
HEURISTIC ANALYSIS Biorefinery Design

SCENARIO A' Ethanol + XOS + Lignin (CHP)



- XOS purification with membranes (UF/NF)

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30,000	4,475	6,802	2,866
40,000	5,967	9,070	3,822
50,000	7,459	11,337	4,777
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90,000	13,426	20,407	8,599
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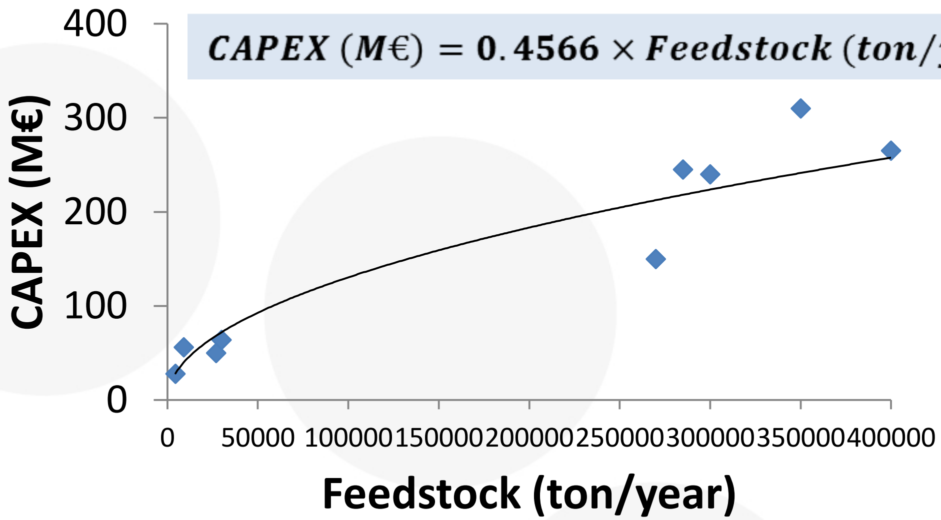

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$$Cumulative\ Cash\ Flow\ (€) = -CAPEX + \sum_{i=1}^{n}(Sales - OPEX)$$

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OPEX)

SCENARIO A' EtOH + XOS + Lignin

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2) Operating Costs		
Distillation	65	€/ton
Steam (Pretreat./Evapor.)	10	€/ton
Purification (XOS)	8*	€/ton hydrolysate
3) Labour		
Personnel costs	2500	€/month
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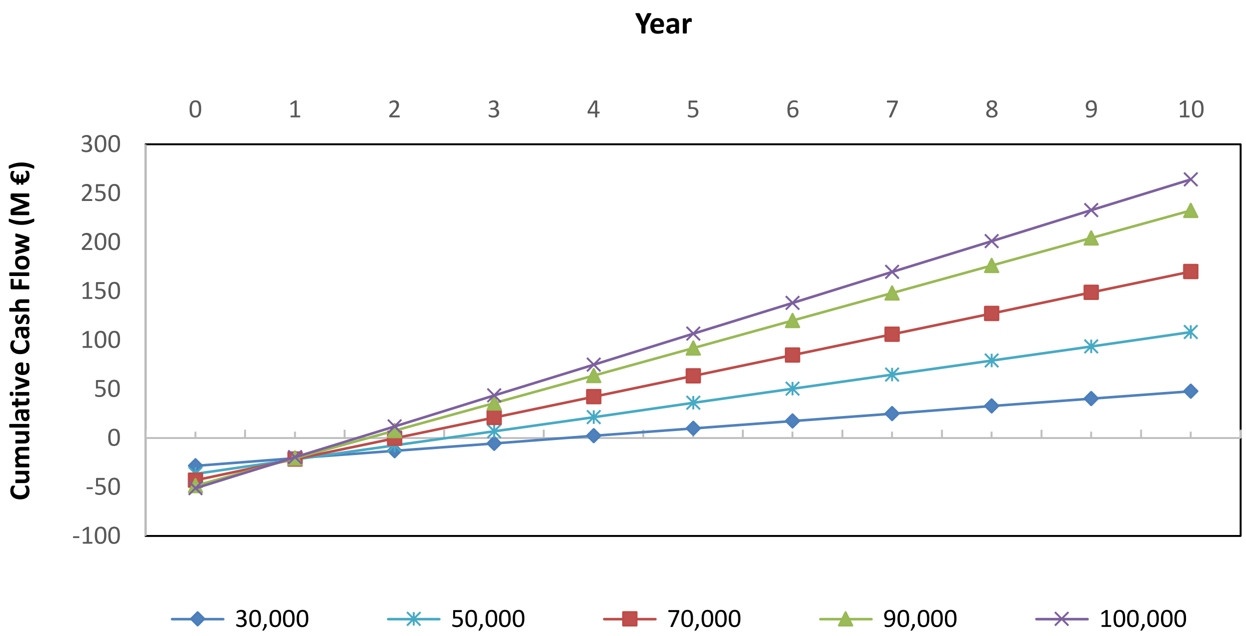
Cash Flow

SCENARIO A' EtOH + XOS + Lignin (CHP)



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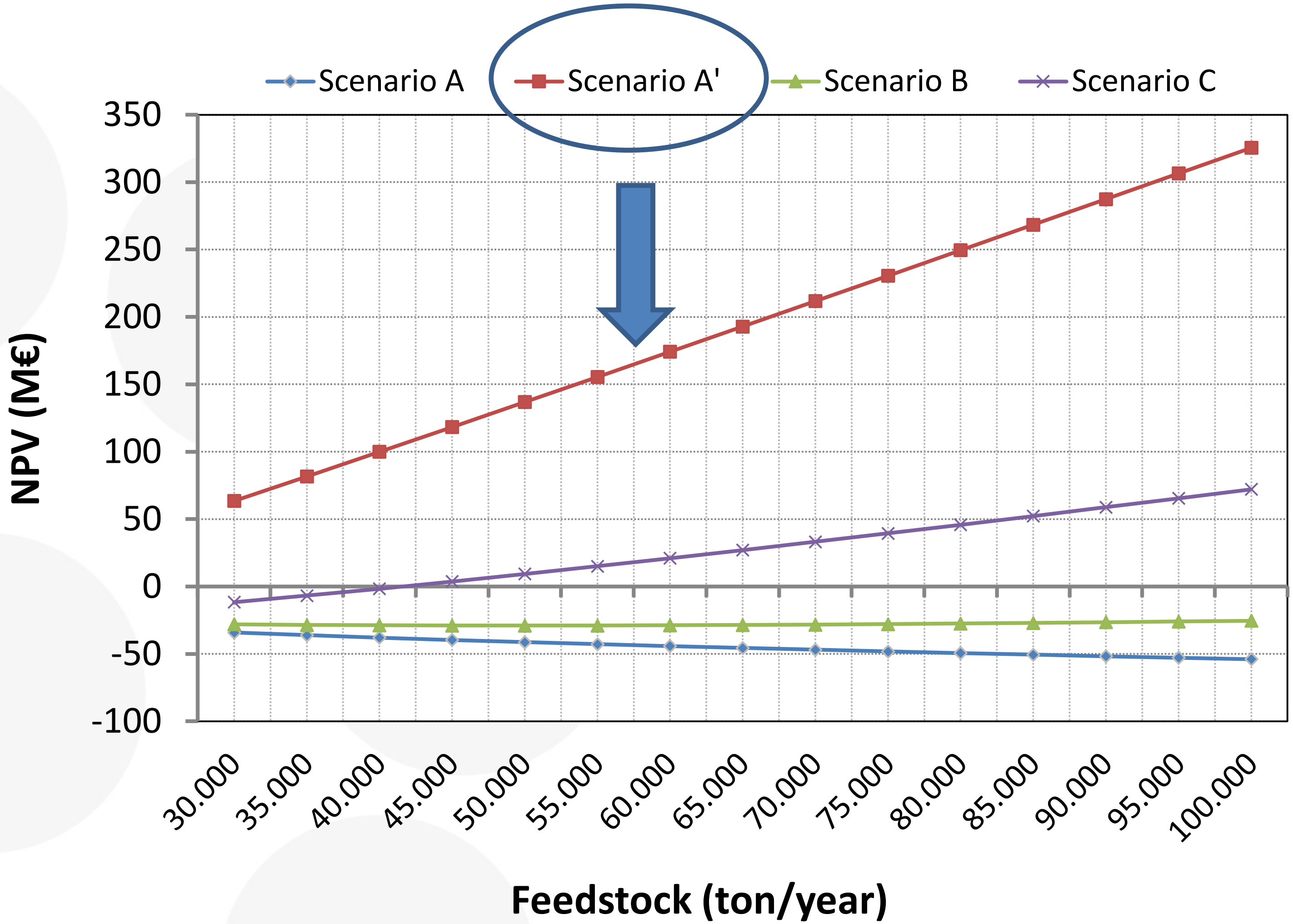
Net Present Value vs. Scale

SCENARIO A' Ethanol + XOS + Lignin (CHP)



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HEURISTIC ANALYSIS Conclusions

SCENARIO A’	Ethanol + Xylooligosaccharides (XOS) + Lignin (CHP)

- **Viable** for any scale (among the available feedstock range)
- Ethanol Production: 15,540 – 51,500 L/day
- Ethanol Production Cost: 0.63 – 0.95 €/L

LNEG

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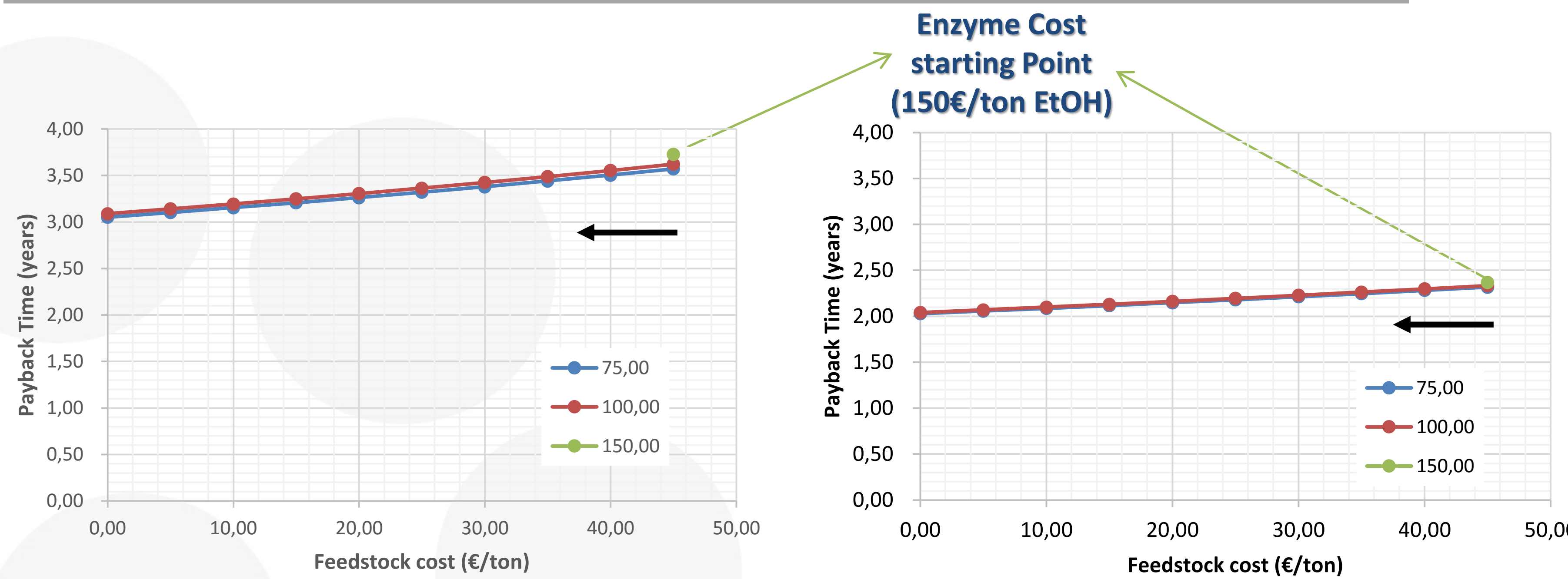
HEURISTIC ANALYSIS Sensitivity Analysis: Enzymes and Feedstock cost

SCENARIO A' Ethanol + XOS + Lignin (CHP)



30,000 ton corn stover/yr

50,000 ton corn stover/yr

- **Viable scenario →** <u>small change in PBT</u> with enzyme and feedstock cost variation

The SMIBIO project is implemented in the framework of ERANet-LAC, a Network of the European Union (EU), Latin America and the Caribbean Countries (CELAC) co-funded by the European Commission within the 7th Framework Programme for Research and technology Development (FP7).

More Info:

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Join us on the way to more sustainability!!

Thanks/Gracias/Obrigado

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