A sustainable supply chain design for Phase III Biorefinery: A Colombian case study

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Global challenges and efficient use of natural resources

Global Challenges

- Energy security → Need for new fuels
- Oil deployment → Biobased products

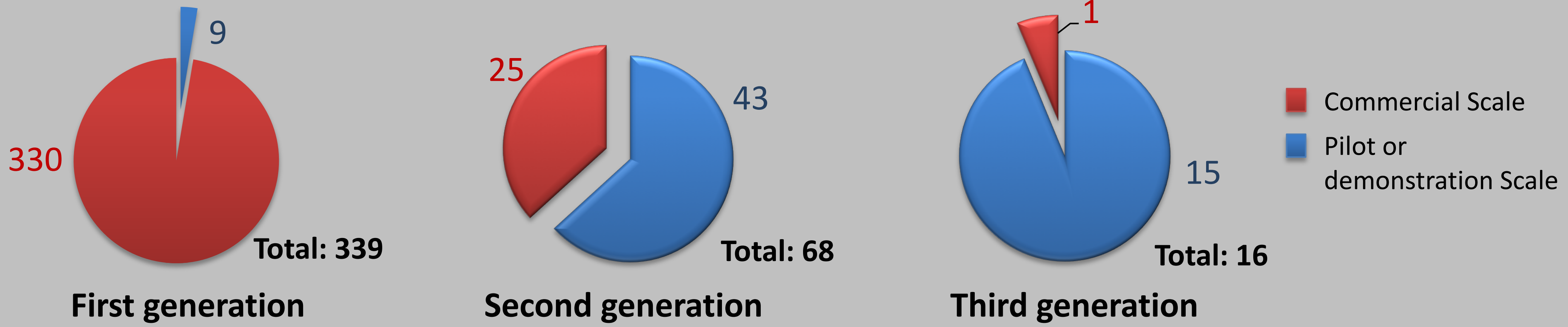
- Greenhouse gas emissions
- Food security
- Biodiversity preservation
- Water management
- Rural development promotion
- Economic value generation

The objective is to made an efficient use of natural resources in biorefineries on a context of sustainable development

(ONU, 2000; Department of Energy, 2015; Interreg 2 Seas European Program, 2017)

Biorefinery issues

Biorefineries worldwide by type of feedstocks for 2016 (Dovetail Partners, 2017):



- **Undesirable and unexpected environmental impacts (Nguyen et al., 2017 ; Bautista 2016).**
- **Land use choices (Nguyen et al., 2017).**
- **Food vs. fuel issues for first generation biorefineries (Nguyen et al., 2017).**

Also, biorefineries producing biobased products have been developed slower than expected (6 over 423), due to:

(Nguyen et al., 2017)

- The investors' perception of high technological risk (Valdivia et al., 2016)
- **Low profitability,** due intensive capital costs and the low prices for biobased products (Valdivia et al., 2016)
- **Lack of a well-defined logistics model** (Valdivia et al., 2016)

Biorefinery potential solutions

Thus, in order to promote the development of the sustainable phase III biorefinery industry the following aspects must be consider simultaneously

- Optimization of the biorefineries supply chain network
- Integration of preprocessing process in the supply chain
- Raw material and final products diversification, including high-value final products.
- Integrate sustainability issues within the context of the territory where the project will be deployed.

Nguyen et al., 2017; Espinoza Pérez et al., 2017; Valdivia et al., 2016; Lamers et al., 2015; Kim et al., 2011; Dunnett et al., 2008

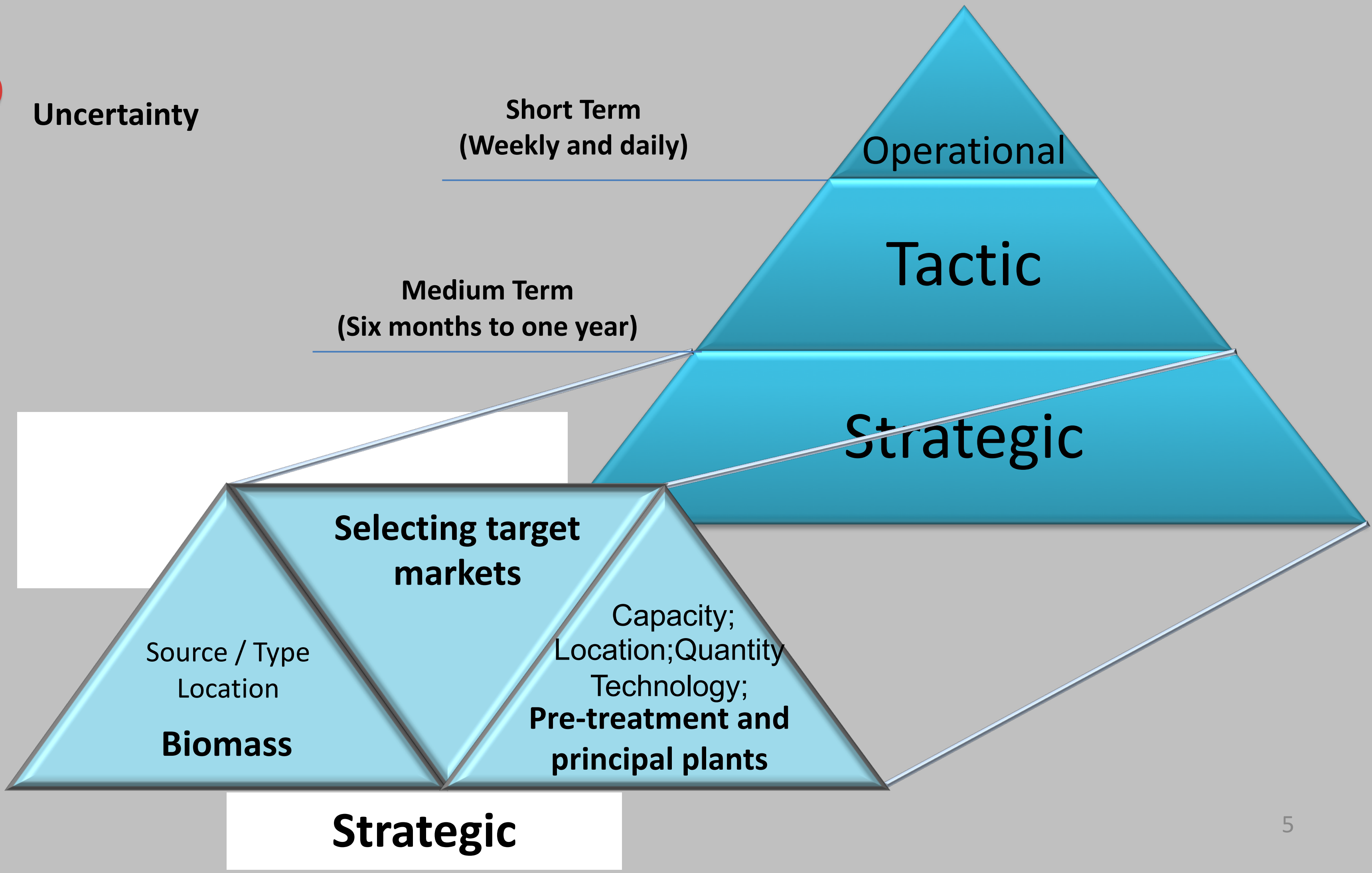
Supply chain Decision-Making levels

(Iakovou, E., et al., 2010; Venugopalan, J., et al., 2014; Mortazavi et al. 2015)

Time

Level of investment

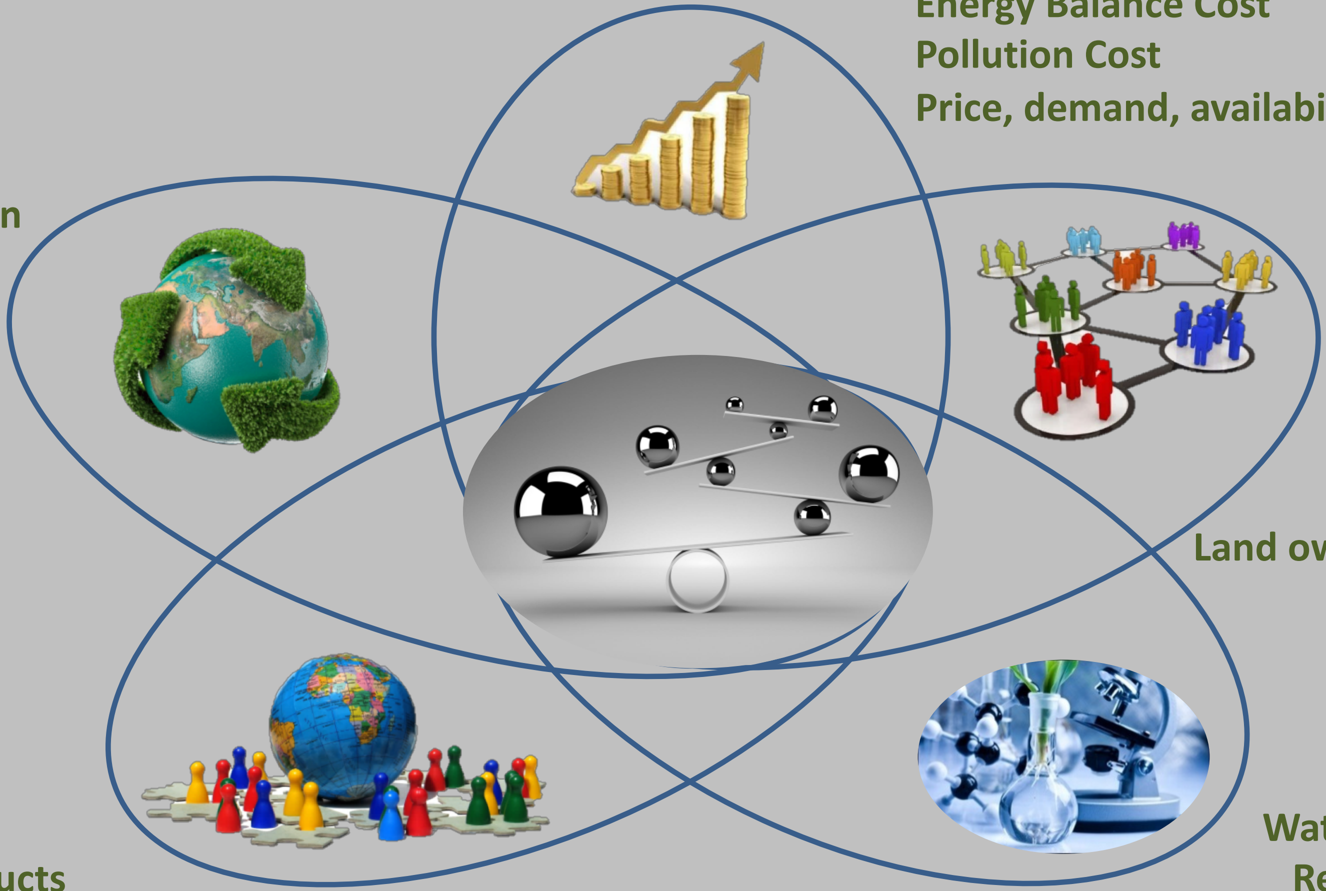
Uncertainty



Sustainable assessment to measure the potential project performance

Capacity Use; Net Present Value
Energy Balance Cost
Pollution Cost
Price, demand, availability variations

Pollution generation
Greenhouse gas
Sewage water



Jobs generated
Land restrictions
Land ownership concentration

Tax reductions
Subsidy
Price control
Advanced biobased products
Demand satisfaction with biobased products

TRL levels
Water consumption
Required hectares
Operational cost reduction by apprenticeship

Bautista, S., et al., 2016a; Bautista, S., et al., 2016b; Global Reporting Initiative, 2016

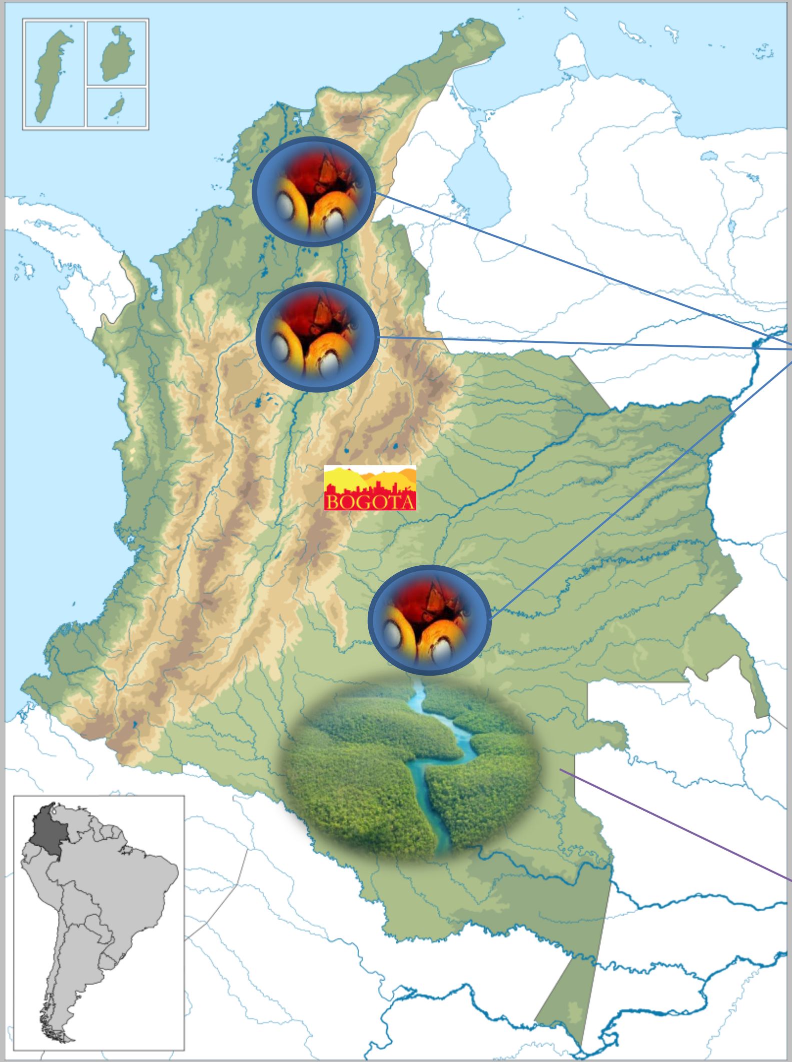
Model formulation

Objective functions	Sustainability dimension included				
	Economic	Political	Environmental	Technological	Social
Max net present value	■	■	■	■	
Max demand satisfaction with biobased products		■			
Min total water use			■	■	
Max TRL				■	
Min GINI					■
Max capacity use	■				
Max use of noon-food crops as raw materials (Advanced)		■			
Max certified land use		■			
Min raw material use			■	■	
Min hectares required			■	■	
Min governmental expenditures		■		■	
Min water used in process			■	■	
Min land selection with high dispersion values					■
Max work generation					■
Min gas emissions for biobased product consumption /CH_4 – N_2O			■		
Min water deterioration / Nitrates – Phosphorus - Phosphates			■		
Min wastewater generation			■		
Min solid waste generation			■		
Min CO_2-equivalent emissions			■		
Min Energy balance (Input-Output)			■		
Min nonrenewable fuel sources used			■		

Integrated Model

Total Objective Function	**22**
Total Parameter	**89**
Total Restriction	**19**
Total Decision Variable	**13**

Colombian case study



Total biodiesel production capacity: **661,000 ton**

Biodiesel production in 2015: **514,000 ton**

Amazon Rainforest

Impacts of biodiesel production in Colombia:


Energy consumption


Emission of gaseous pollutants in the biodiesel life cycle (There are contradictory positions across studies)


Loss of biodiversity


Water quality and availability


Food security

Colombian case study

Raw Materials

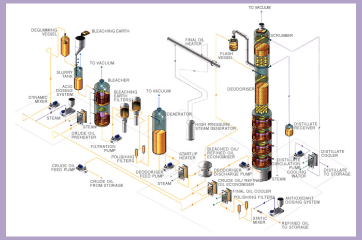
8 potential locations

Jatropha curcas
Crude oil
(non-edible crops)

Palm Crude oil

Pretreatment

8 potential locations



One technology:
Physical refining

Three production capacity :
40,000; 80,000 and 120,000 t/year

Main Production Plants

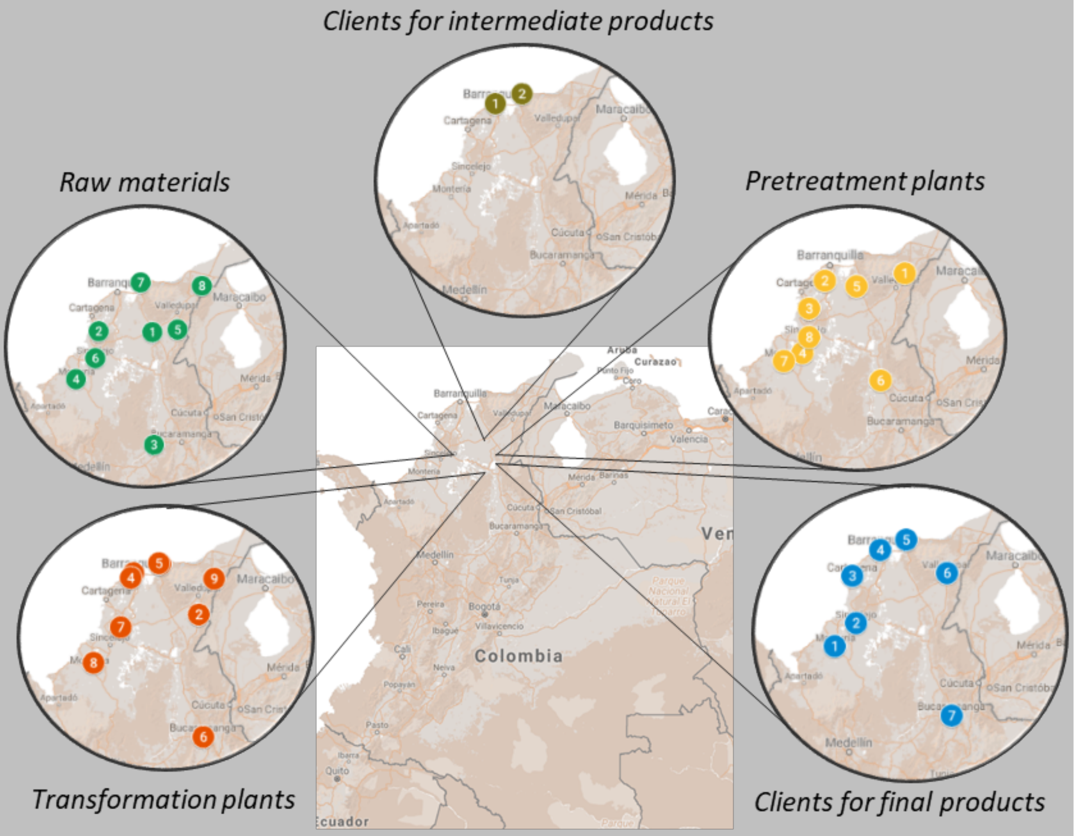
8 potential locations

Six production technology mixing:
Alkaline transesterification
Co-Current transesterification
Counter-Current transesterification
Production of biopolyester from glycerol

Three production capacity :
40,000; 80,000 and 120,000 t/year

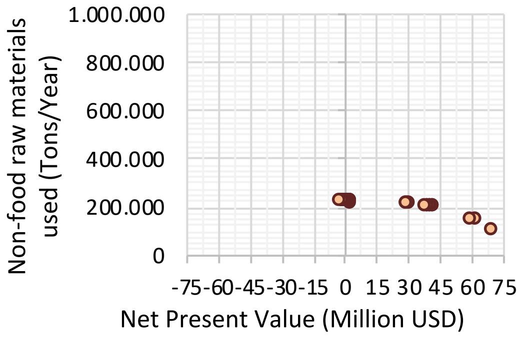
Markets

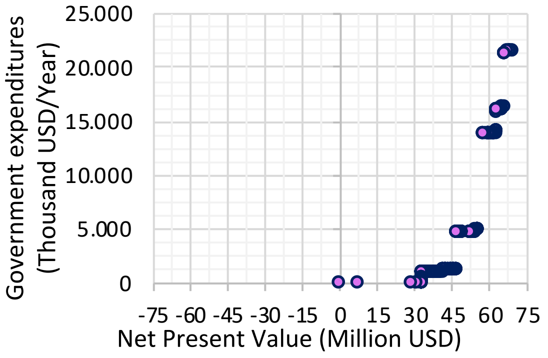
9 potential locations:
7 final products
+
2 intermediate product



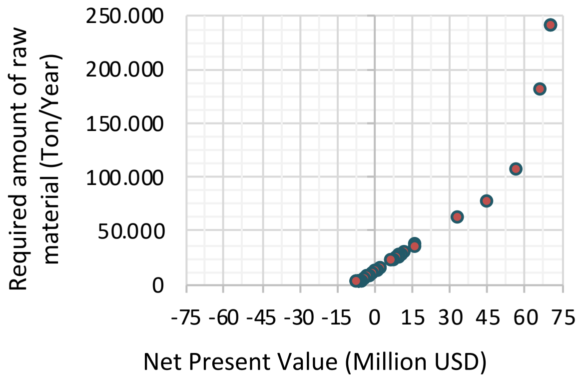
Multiobjective optimization results

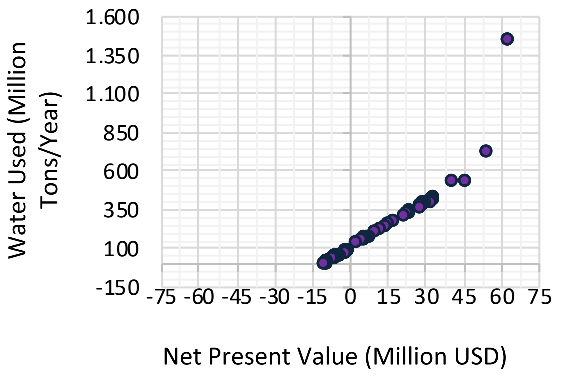
Political



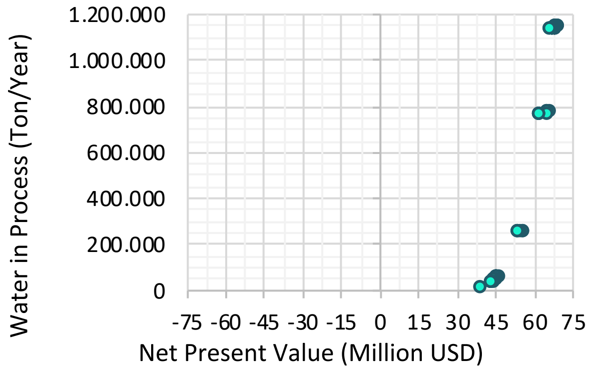


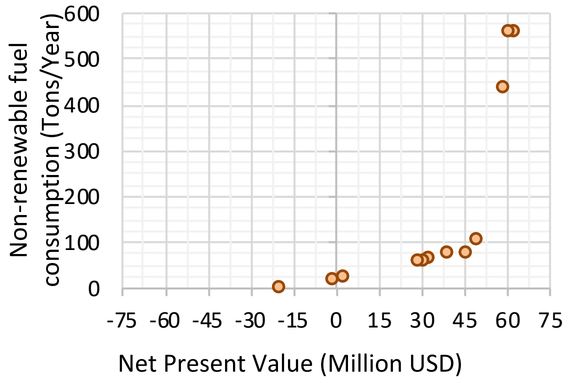
Environmental



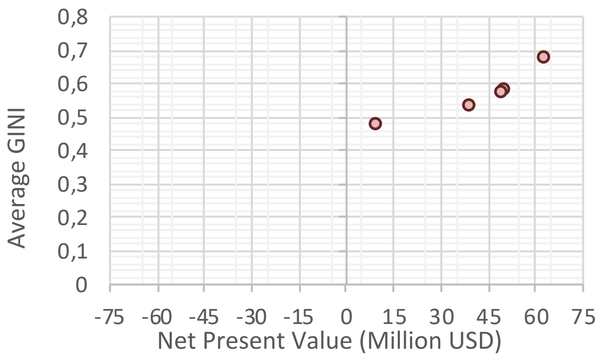


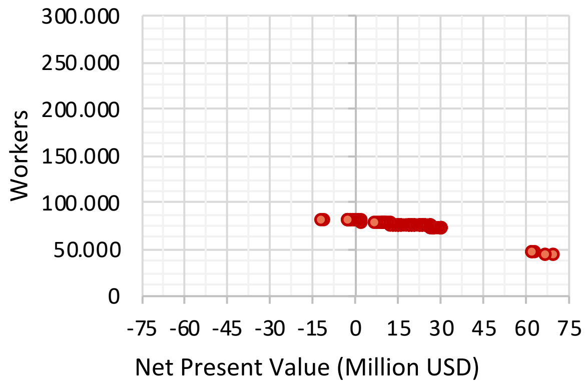
Technological





Social





Conclusions

The **integrated model** for the **early design stage in Phase III biorefineries** from a **sustainable and holistic point of view** enables to realize a comprehensive ex-ante evaluation for the project performance.

The translation of the **157 sustainability indicators into 21 general objective functions** (and 5 restrictions) helps to simplify the next step related to formalization of stakeholders preferences

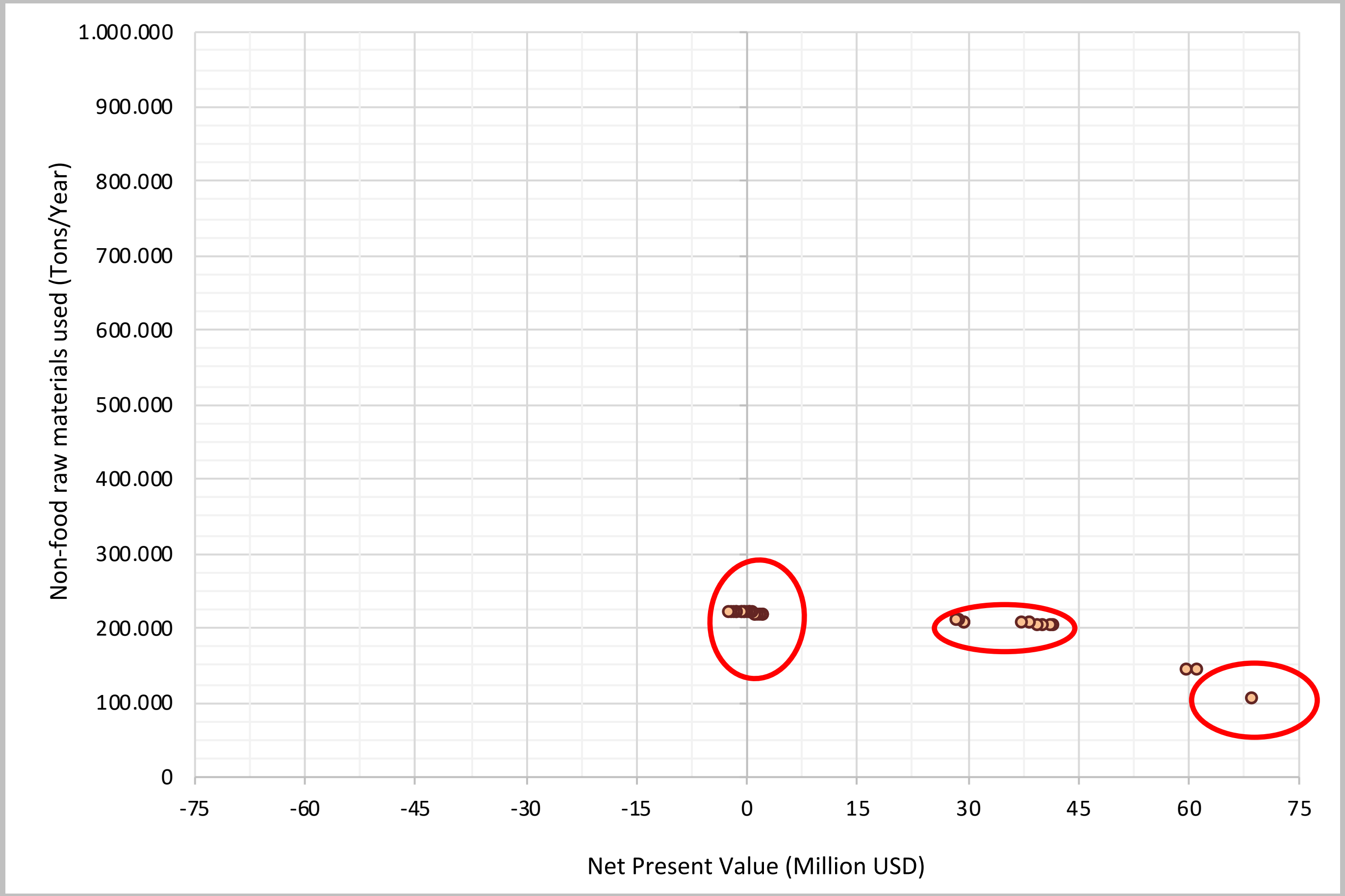
Other objective functions can be integrated in the model, as the payback time for the investment. And some of the objective functions can be **regrouped**.

Higher theoretical transformation yields → Selection of **emerging technologies**

The **risk and uncertainties related to emerging technologies** must to be determined in future to provide more comprehensive information to decision-makers.

Perspectives

Create a questionnaire in order to **formalize stakeholder preferences** using Multiple-criteria decision-making (based on all pareto front found).



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