Potential of residues to biotechnological conversion. Case study: Detailed Economic Assessment of polylactic acid production using glucose platform from sugarcane bagasse, coffee cut stems and plantain

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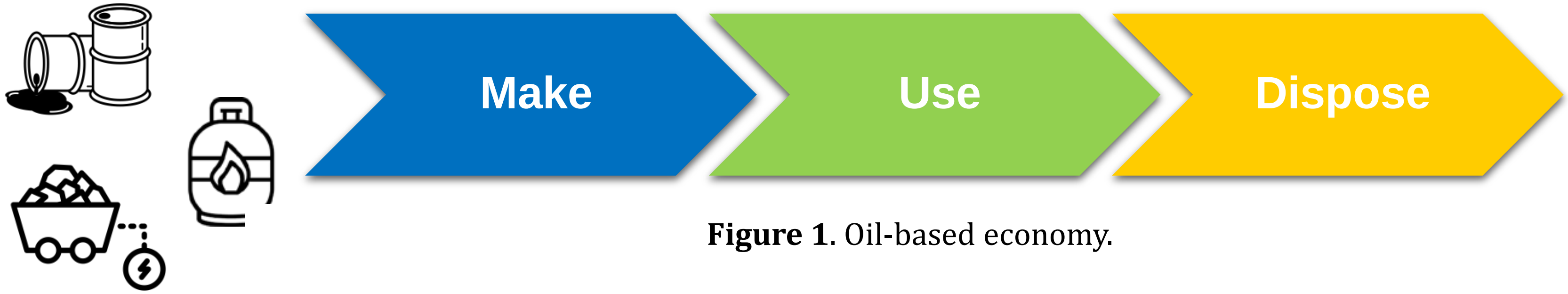


Figure 1. Oil-based economy.

- ✓ Global Warming
- ✓ Ozone depletion
- ✓ Natural resources pollution
- ✓ Acid precipitation
- ✓ Oil spills

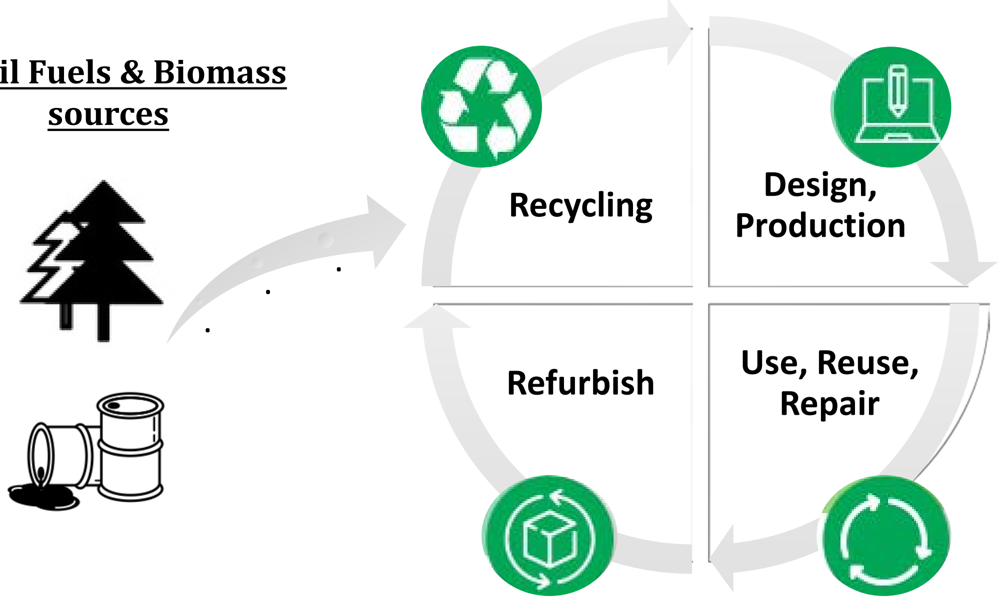


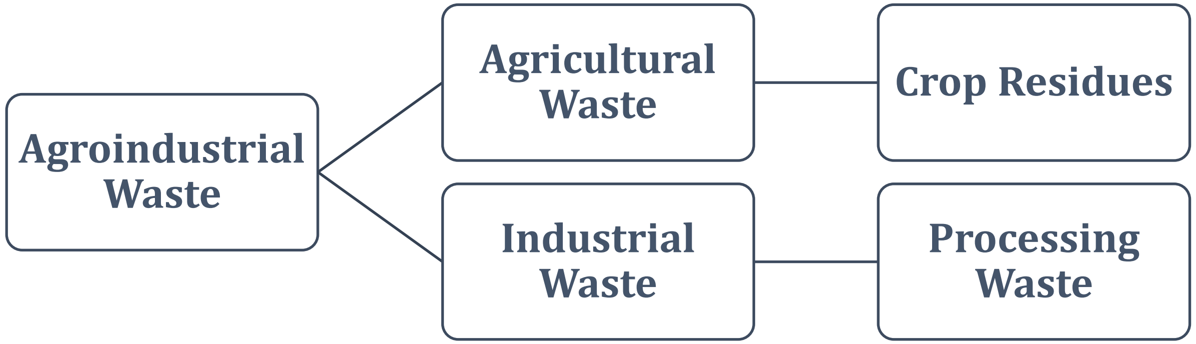
Figure 2. Efficient use of finite resources through circular economy.

Advantages

- ✓ New Green industries
- ✓ Less oil-based products
- ✓ Less pollution
- ✓ New profit opportunities

In Colombia, 2.8% of Gross Domestic Product (GDP) was contributed by the agricultural and agroindustrial sector [1], with a growth of 6.8% [2] in 2020

1. Introduction



The sectors related to agroindustrial waste products are growing. Therefore, there is an increase in publications showing the enormous potential to enter the market with new product alternatives.

The process for added-value production from biomass is based on the sugar platform

LIGNOCELLULOSIC BIOMASS

Cellulose and hemicellulose present in biomass are the fractions used to produce fermentable sugars (i.e., **C5** and **C6**).
Acid hydrolysis and saccharification are the most widely used methods [3].

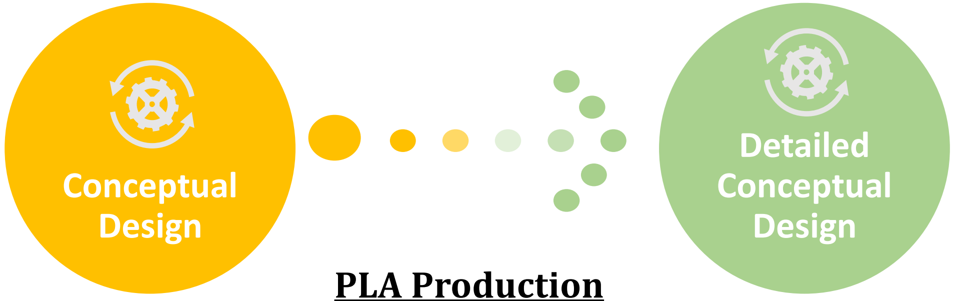
Agroindustrial waste of interest in the Colombian context

Sugarcane Bagasse (SCB)

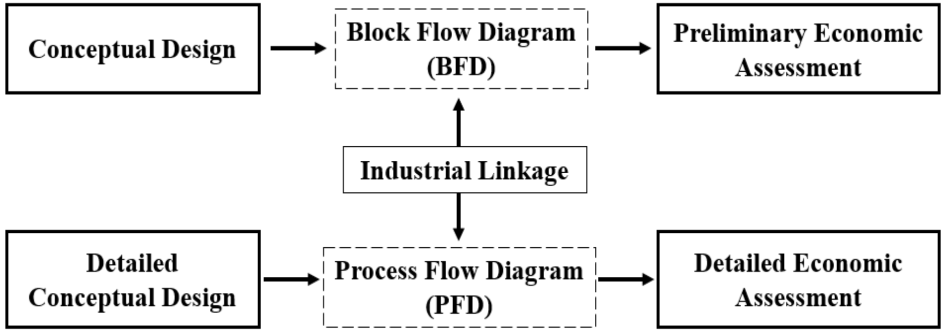
Coffee Cut Stem (CCS)

Plantain Peel (PP)

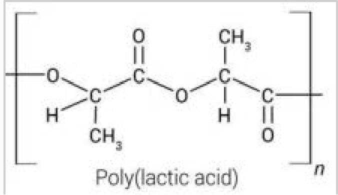
1. Introduction

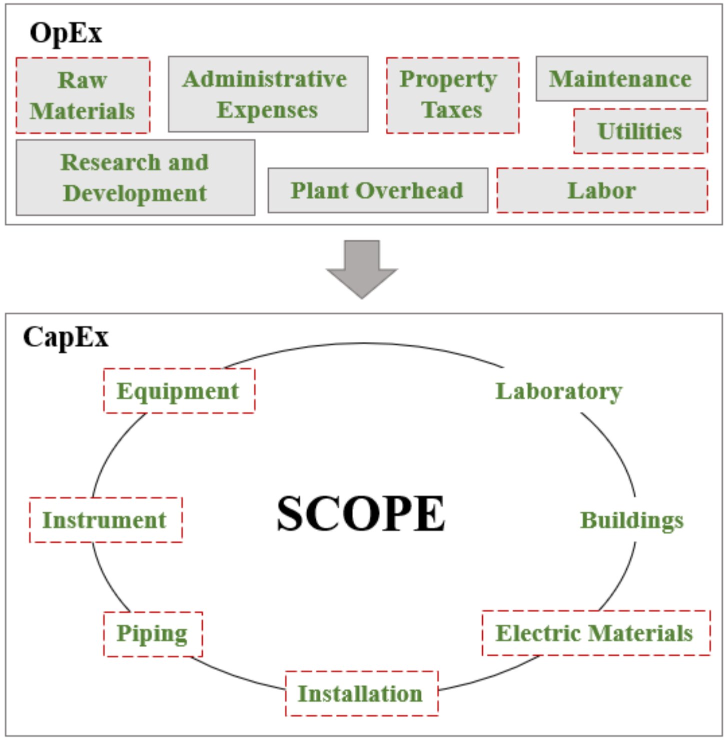


PLA Production



A product of great scientific and industrial reception is polylactic acid (PLA) [5]



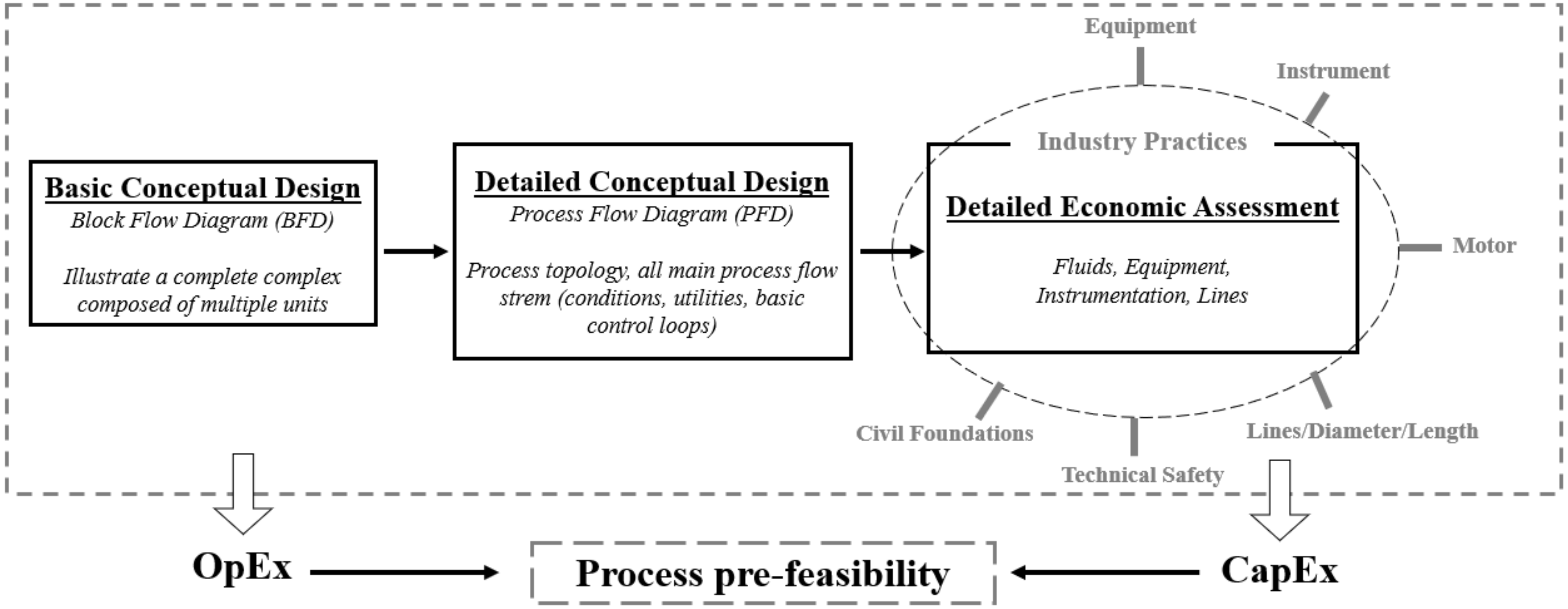


Detailed economic assessment is a tool used for making investment decisions in the conceptual design stage: CapEx and OpEx

2. Research objective

This work focuses on the detailed economic evaluation of PLA production considering glucose platform obtained from SCB, CCS and PP

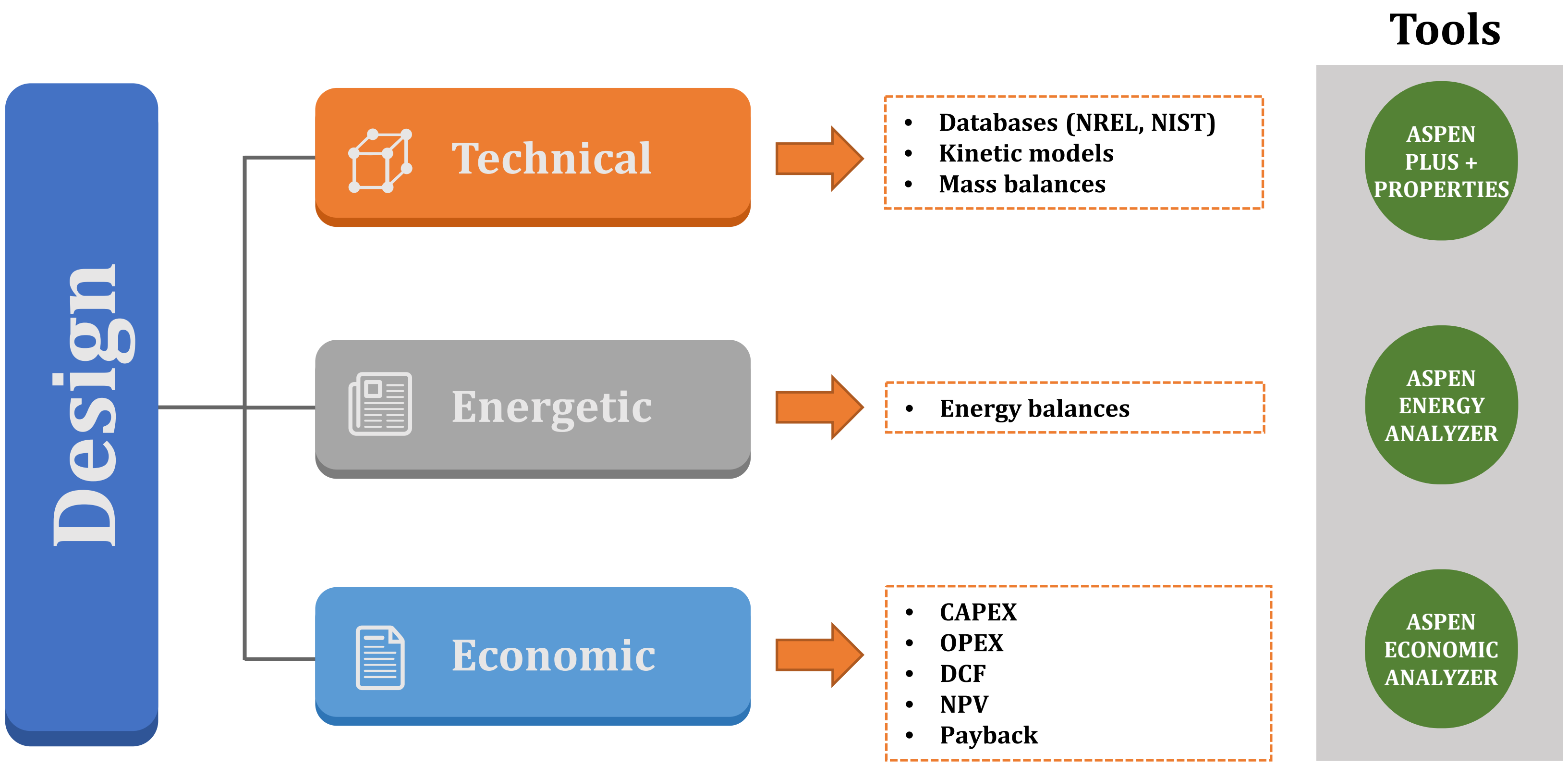
The detailed economic assessment methodology was defined integrating basic conceptual design and detailed conceptual design



3. Methodology

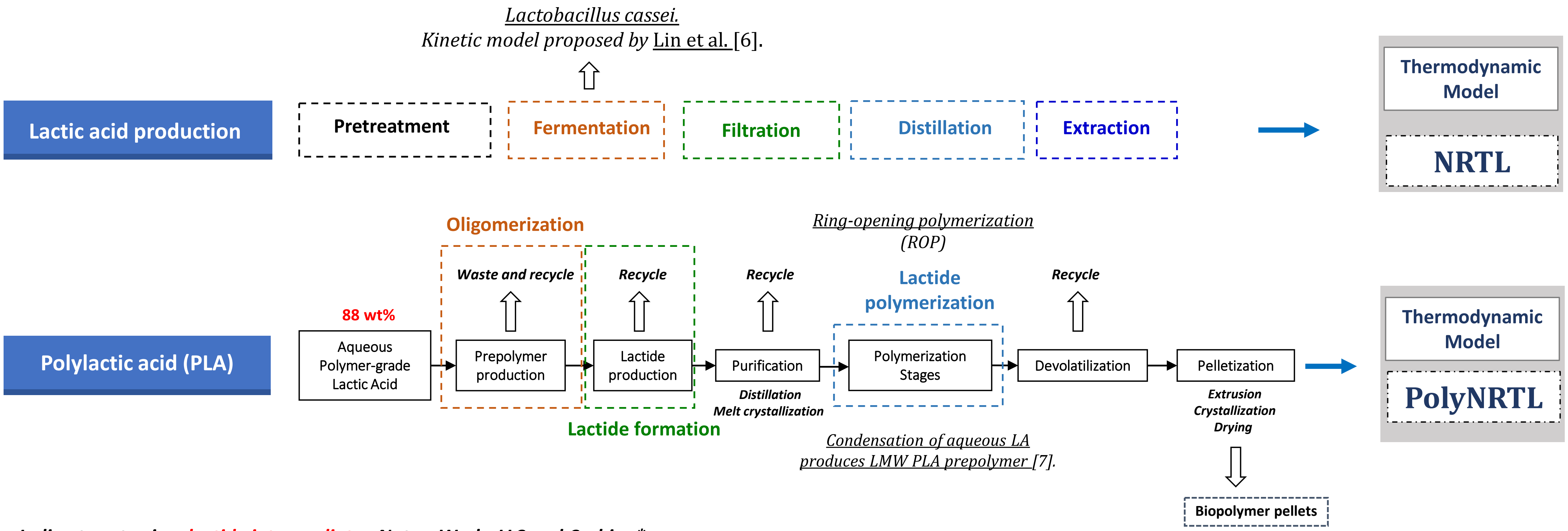
Conceptual design: aspects for economic analysis

In the case of PLA production, the process simulation was considered glucose platform from SCB, CCS, and PP



3. Methodology

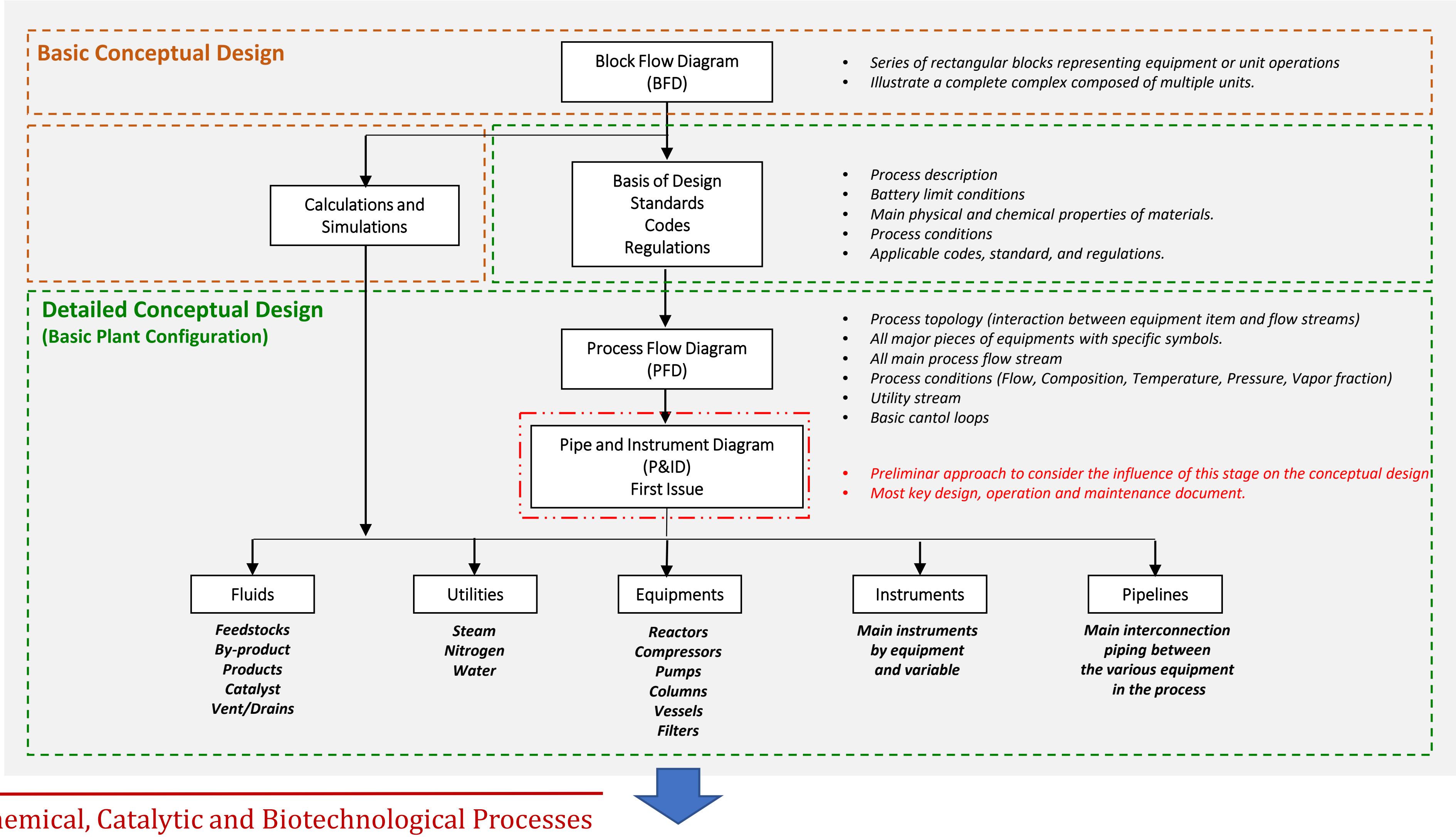
Glusose : Lactid acid : Polylactic Acid



- *Indirect route via a lactide intermediate : NatureWorks LLC and Corbion*.*
- *Including distillation and melt crystallization***
- *Including crystallization and drying****

3. Methodology

Approach to Detailed Conceptual Design



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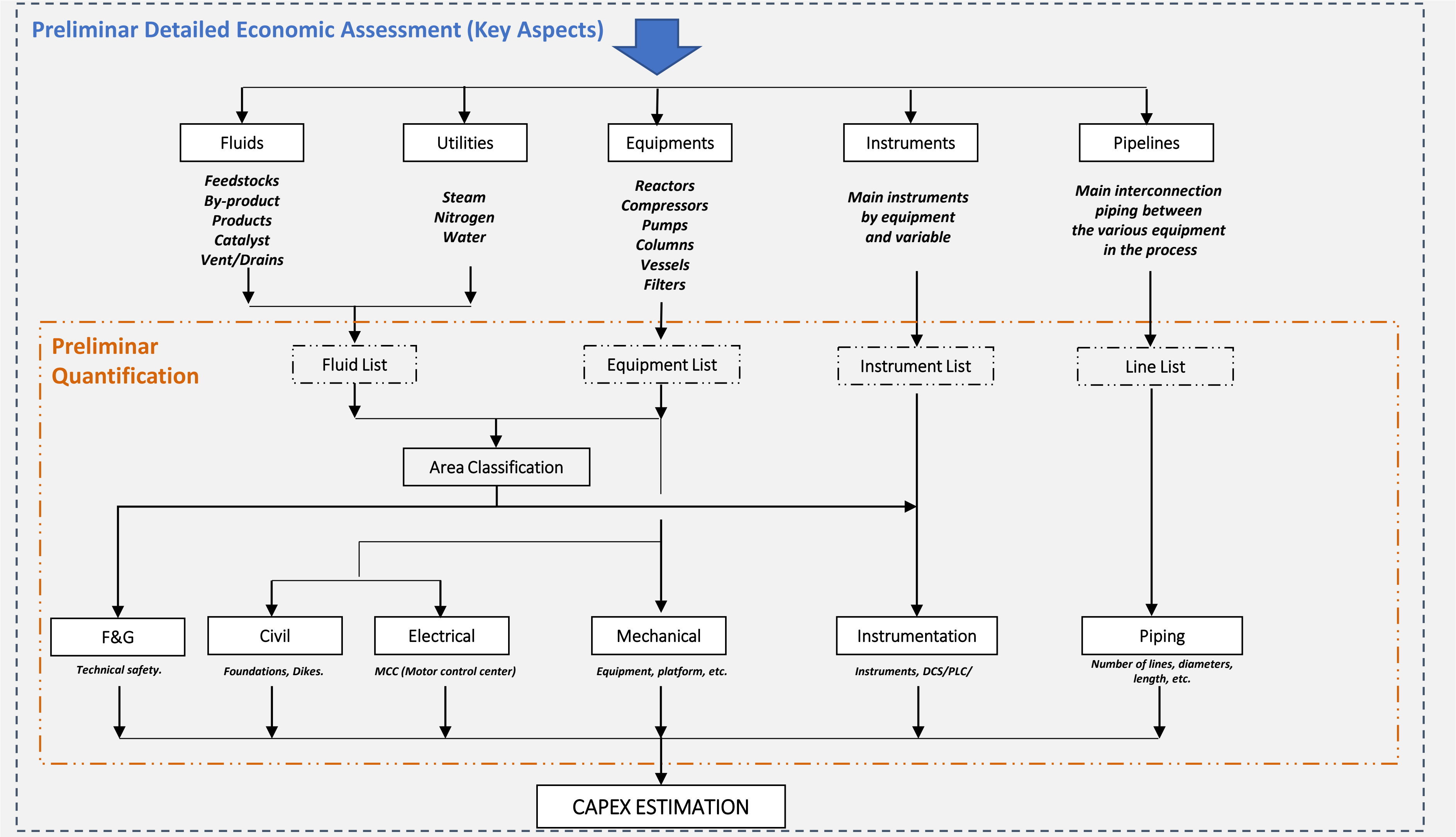
3. Methodology



3. Methodology

Production scale: 5.4 Ton/day.

Table 1. Operational costs for PLA production of 2000 MT/yr from different platform: CCS, SCB, PP.

Type	Units	Consumption			Costs (kUSD)		
		CCS [13]	**SCB** [12]	**PP** [14]	**CCS** [13]	**SCB** [12]	**PP** [14]
Reactants							
Raw material	MT/yr	27749	109749	112712	499	1975	2029
Sulfuric acid	MT/yr	4039	3042	2244	380	286	211
Enzyme	MT/yr	1935	1094	1421	426	241	313
Utilities							
Water	MT/yr	256497	212279	238721	256	212	239
LP Steam	MT/yr	14782	22704	22516	1	2	2
Energy	kW-h/yr	21705	43231	39135	2	3	3
Operating labor							
Operation	-	-	-	-	34	34	34
Maintenance	-	-	-	-	10	10	10
Sugar Yield	g/Ton RM	450.7	114	111	-	-	-
Operational Expenses Summary per Platform		**Utility costs (kUSD/yr)**			393	351	377
		Annual OpEx (kUSD/yr)			1609	2764	2840
		Capacity (MT/yr)			2000	2000	2000
		Production cost (USD/MT)			**804**	**1382**	**1420**

Notes:
***CCS**: Coffee cut stem; **SCB**: Sugarcane bagasse; **PP**: Plantain, **RM**: Raw material*
+Hours of operation: 8766 h/yr

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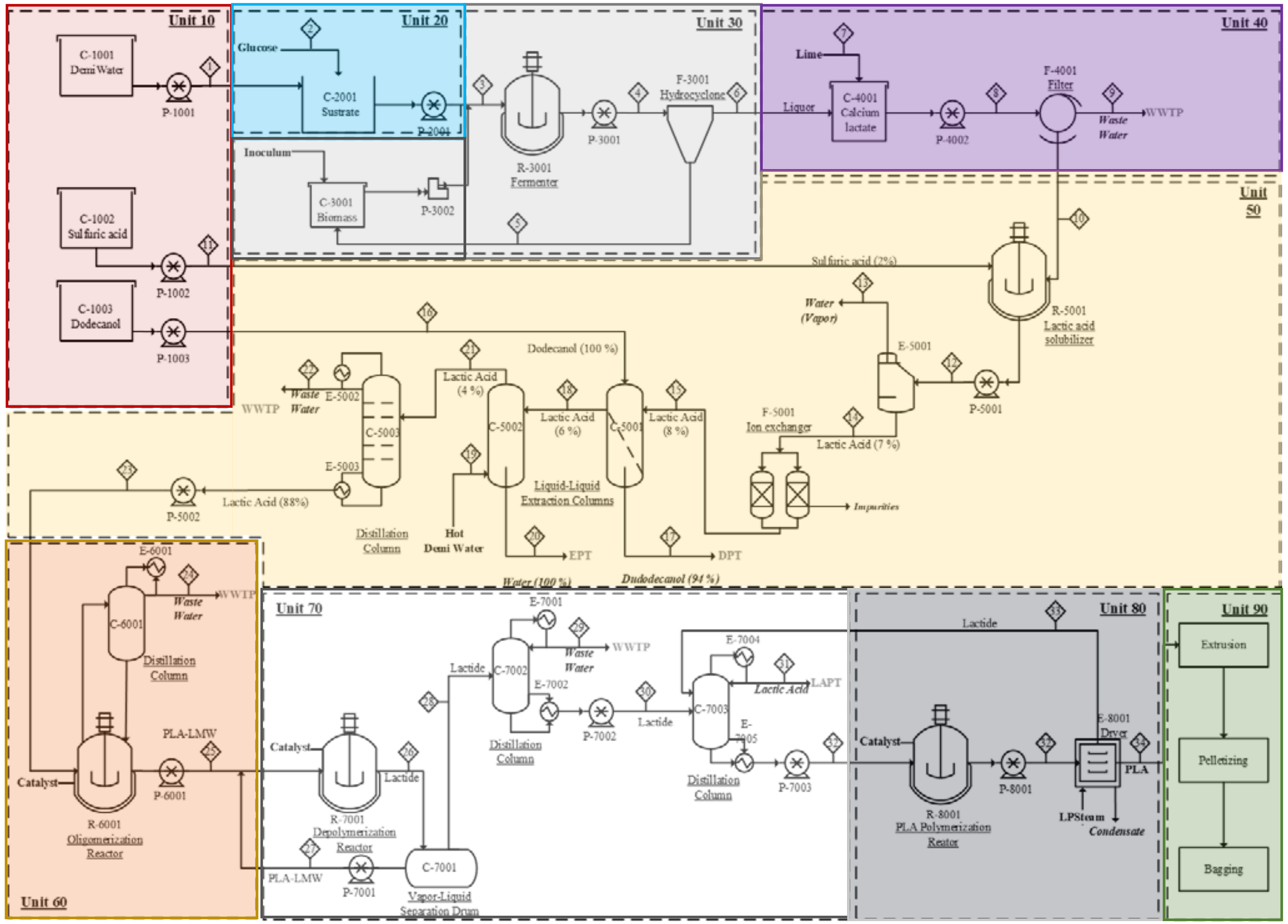
4. Results

PLA production process
(From feedstock to product)



Process Flow Diagram (PFD)

↓

Categorized by Process Areas

↓

Equipments identified per area

↓

Accurate PROCESS SCOPE

Storage AREA 10 → Pretreatment AREA 20 → Fermentation AREA 30 → Precipitation AREA 40 → Purification AREA 50 → Polimerization 1 AREA 60 → Polimerization 2 AREA 70 → Polimerization 3 AREA 80 → Extusion, Pelletizing, Bagging

4. Results

Table 2. Mass and energy balances of the PLA production process

Components (wt%)	1	2	4	7	9	13	17	19	20
Water		100	88,38	65	68,87	99,62	4,15	100	100
Glucose	100		0,03				2,04		
Lactic Acid			9,91			0,38			
Biomass			1,68						
Lime				35	31,13				
Dodecanol							93,81		Trazes
Load, MT/batch	0,40	**39,60**	44,96	1,18	39,98	2,94	7,45	4,09	3,09
Mass Flow, kg/min	0,04	-	4,50	-	4,00	-	0,74	0,41	0,31
Pressure, barg	2	0	1	0	1	0	3	3	2,5
Temperature, °C	30	30	42	30	50	100	180	80	80
Components (wt%)	22	23	24	25	26	29	31	32	34
Water	99,98	88	99,94	1,98	13,58	100		92,35	
Lactic Acid	0,02	12	0,06	9,56	0,49		100	6,65	
Catalyst					2,34			1	
PLA, LMW				88,46	67,46				
Lactide					16,13				
PLA, HMW								0,82	100
Load, MT/batch	0,32	0,62	0,35	1,14	2,44	0,08	0,06	7,10	0,78
Mass Flow, kg/min	0,03	0,06	0,04	0,11	0,24	0,01	0,01	0,71	0,08
Pressure, barg	1	1	0,55	1	0,5	0,5	1	1,5	3
Temperature, °C	100	125	100	170	200	100	100	100	120
MW, gr/mol					1048,3			192821	192821

4. Results

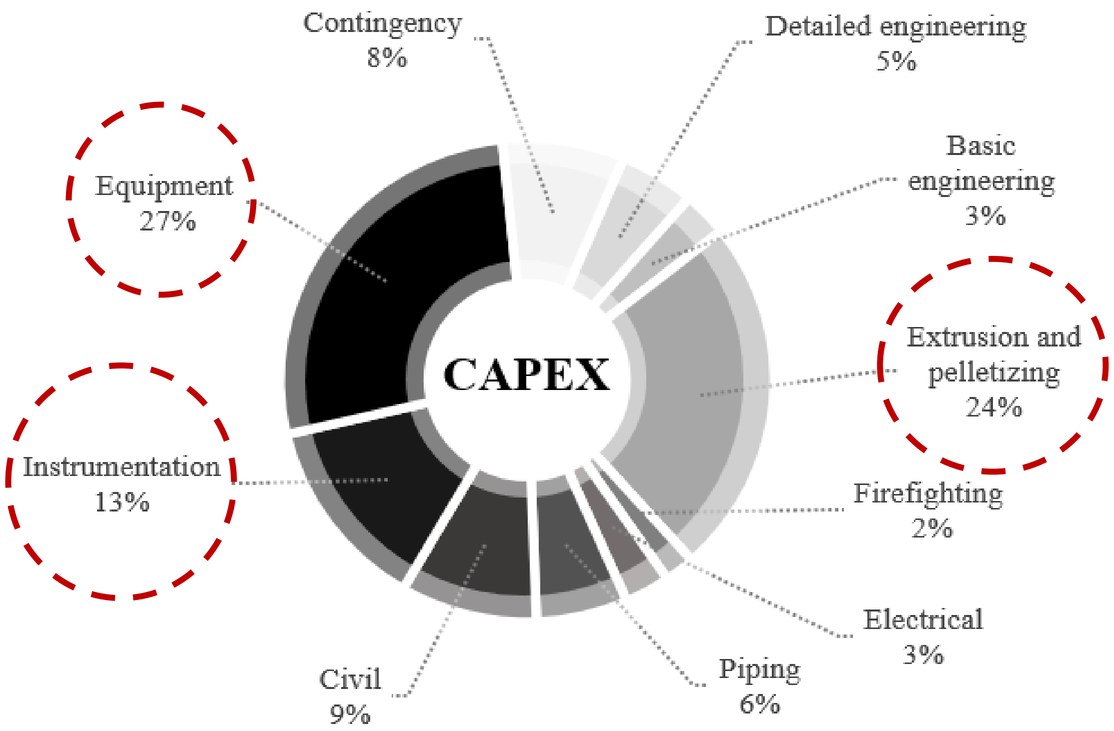


Figure 3. Percentage distribution of the CapEx by cost category for the PLA production

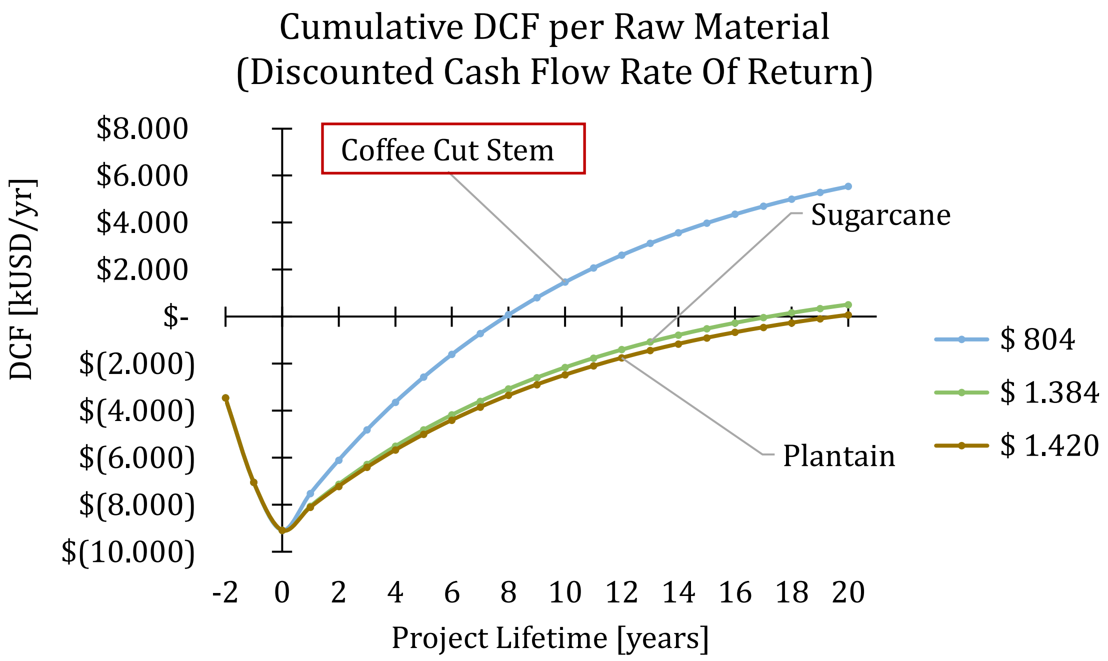


Figure 4. Performance Process flow diagram of the PLA production process.

4. Results

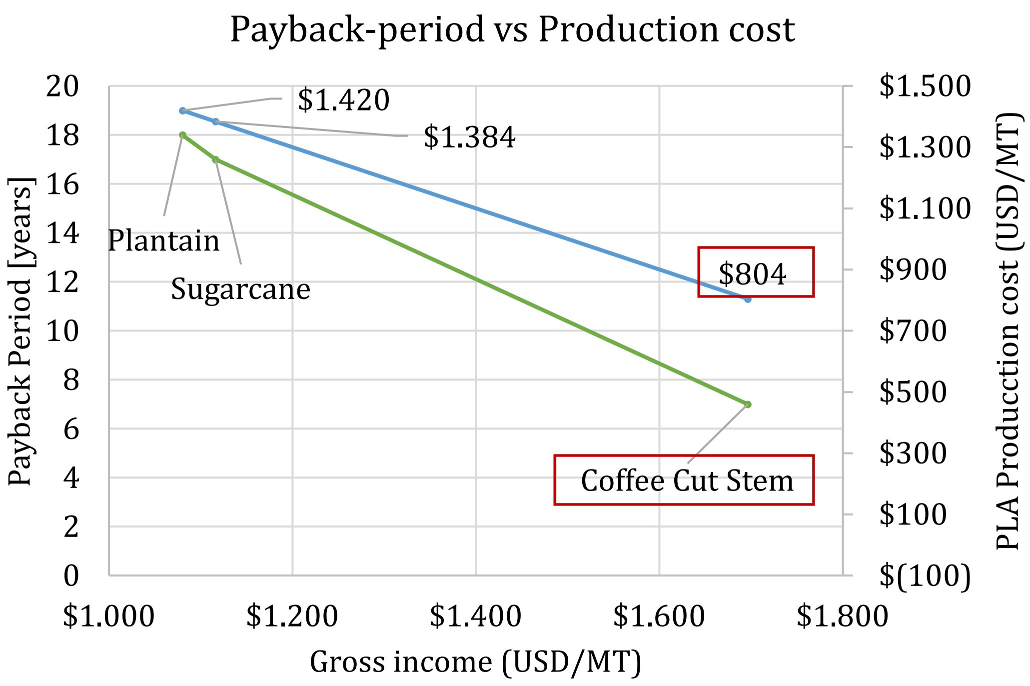


Figure 5. Performance Process flow diagram of the PLA production process.

Polylactic Acid

- **Sales Price: $ 1480 – 1880 USD/MT**

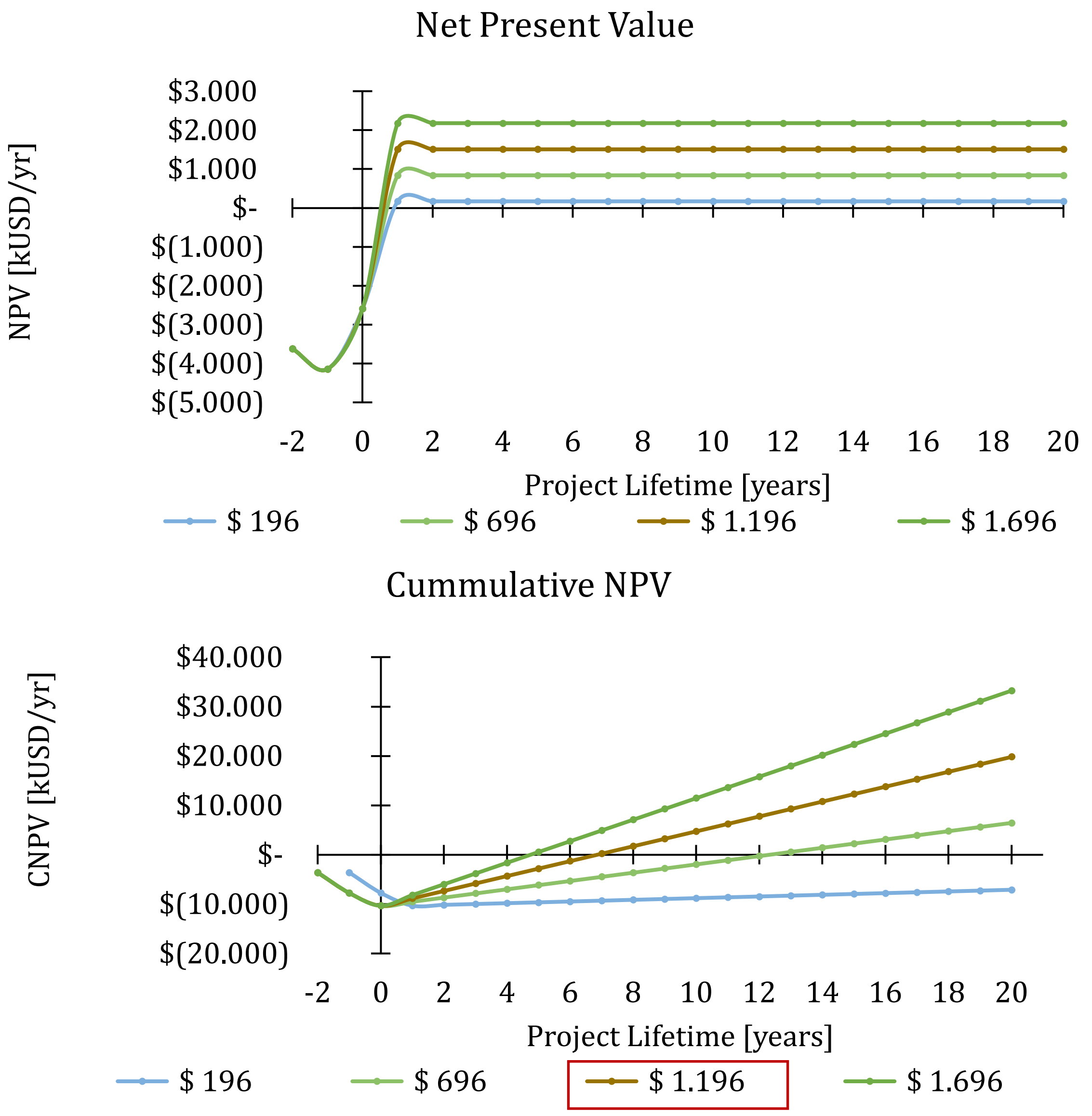


Figure 6. Economic assessment of PLA production from CCS. NPV over project lifetime at various gross incomes.

5. Conclusion

Despite the raw material, the gross income must be higher than USD 1000-1500/MT of PLA to have a payback period lower than 10 years. In this way, the best raw material to reach the process economic feasibility was CCS.

Raw material characteristics such as low moisture content, high availability, and easy transportation are necessary to implement the PLA production process in the Colombian context. Nevertheless, efforts addressed to improve these aspects for the CCS are required.

The inclusion of industrial aspects into the economic assessment of conceptual designed biomass upgrading processes improve the quality of the CapEx and OpEx estimations giving more reliable results.

6. Acknowledgments

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"Business and innovation competencies for economic development and productive inclusion of the regions affected by the Colombian conflict"
SIGP code 58907. Contract number: FP44842-213-2018

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