Version ORANGE

3. RESULTS

3.1. Technical Assessment

Results for different scenarios with first generation and the integration of the first and second generation are presented in the Table 03. In the first and fourth scenario, half of the ethanol stream is sent to the production of bio jet fuel, while in the second and third scenario the whole 2nd generation ethanol is converted in the fuel. In the integrated scenarios, two fermenters set were adopted due to the different yeasts used in the first generation and in the second generation. Note that scenarios 1 and 4, 2 and 3 have the same flow rates since they only differ in the initial investment required.

Table 03 – Main flow rates for the bio jet fuel production in different scenarios

Flow rates	Scenario 1 and 4 (per year)	Scenario 2 and 3 (per year)
Sugarcane feed rate	3.000.000 t	3.000.000 t
Straw available to the industry	252.000 t	252.000 t
Sugar Production	193.477 t	193.477 t
Ethanol Production	131.880 m^3	204.969 m^3
Bio Jet Fuel	30.773 t	34.541 t
Electricity Production	218.338 MWh	277.650 MWh
Electricity Surplus from Process Steam	107.785 MWh	106.108 MWh
Bagasse Production	763.200 t	763.200 t
Bagasse Surplus	49.090 t	0 t
Hydrogen Consumption	406 t	456 t

3.1. Economic Evaluation

The economic parameters obtained in this simulation are presented in Table 04.

Table 04 – Economic parameters

Economic Parameters	Scenario 01	Scenario 02	Scenario 03	Scenario 04
LPV (MBRL)	$43.60	$123.90	$994.50	$1,369.90
IRR	13%	14%	30%	47%
Payback time (years)	13.6	11.2	3.1	2.7
Risk Analysis (Monte Carlo)	6.2%	23.3%	1.6%	0.1%

Scenarios comprehending the second generation technology (2 and 4) presents a better economic performance compared to their equivalent without second generation platform (1 and 3 respectively). Even though the higher CAPEX, the ethanol sales are relevant for the economic evaluation. Monte Carlo simulation, on the other hand, shows that a second generation technology presents a higher risk compared to the first generation technology by itself.

Comparing scenarios Greenfield (3 and 4) with their brownfield equivalents (1 and 2), it is possible to see a better performance of the first group. This occurs due to a portfolio diversification is vital for the business success.

Version PINEAPPLE

3. RESULTS

3.1. Technical Assessment

By keeping most of the bagasse for cogeneration (which is the preferred option of sugarcane companies) and feeding the 2G process with straw, the amount of electricity sold to the grid in scenarios 2 and 4 is about the same as in scenarios 1 and 3 (1G plant) (Table 03). Another advantage of scenarios 2 and 4 is that the total ethanol produced in the 1G plant is sold to the market. On the other hand, in scenarios 1 and 3 half of the 1G ethanol production is committed to producing jet fuel.

Table 03 – Main stream flow rates for jet fuel production in different scenarios per year

Parameter	Scenarios 1 & 3 (1G mill)	Scenarios 2 & 4 (1G+2G mill)
Sugarcane (t)	3,000,000	3,000,000
Ethanol 1G Production (m^3)	131,900	131,900
Ethanol 1G sold to the market (m^3)	65,950	131,900
Ethanol 2G Production (m^3)	---	73,000
Electricity Consumption (MWh)	110,500	171,500
Electricity to the grid (MWh)	107,000	108,400
Jet Fuel (t)	31,000	32,500
Bagasse to Boiler (dry ton)	357,000	303,500
Bagasse to 2G Process (dry ton)	---	78,150
Sugarcane Straw (dry ton)	---	214,200

3.2. Economic Evaluation

Estimates of capital (CAPEX) and operating (OPEX) expenses, and revenues for each scenario are presented in Table 04. In the OPEX are not included taxes, depreciation, working capital, and loan interests. Moreover, the sugar plant, the 1G ethanol plant, and the cogeneration unit are not included in the battery limit of the project in scenarios 1 and 2 (retrofit design); consequently, OPEX and revenues are considerably lower when compared with their greenfield counterpart scenarios. In scenario 1, the opportunity cost of ethanol not sold to the market (50% of the production) is part of the OPEX. Likewise, the opportunity cost of electricity was also accounted for in scenarios 1 and 3. In the greenfield design options (scenarios 3 and 4), revenues are markedly higher due to the selling of sugar and the whole production of 1G ethanol. As a consequence of the latter, scenarios with second-generation technology (scenarios 2 and 4) present better economic performance if compared with their 1G counterpart scenarios (1 and 3, respectively), despite higher capital costs (Table 04). This fact answers the research question addressed in this study, i.e. the use of sugarcane straw to produce jet fuel is a promising alternative, especially if the investment is in a greenfield biorefinery (scenario 4).

The higher profitability of scenarios 3 and 4 (greenfield design) is associated with lesser risks of having an IRR lower than 12%. However, this advantage has to be counterbalanced against an enormous CAPEX (near 1 billion Brazilian Real), which makes it difficult to attract investors. Furthermore, in the case of scenario 4, technical risks related to second-generation technologies are still important.

Finally, the selling price of jet fuel considered in this work (R$ 3.30/L) has a premium of 45 cents over the current price of jet fuel in Brazil (R$ 2.85/L). Without premium, only the greenfield design options (scenarios 3 and 4) are economically attractive and with IRR values over the hurdle rate of 12% typically adopted by the sugarcane industry (IRR[1] = 2.0%; IRR [2] = 9.1%; IRR [3] = 28%; IRR [4] = 44%).

Table 04 – Costs, revenues, and economic performance indicators for each scenario

Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 4
CAPEX (MR$)	230	491	725	956
OPEX (MR$)	28	81	269	323
Revenues (MR$)	58	151	572	584
NPV (MR$)	43.60	123.90	994.50	1,369.90
IRR	13%	14%	30%	47%
Payback Time (years)	13.6	11.2	3.1	2.7
Risk Probability (IRR<12%)	6.2%	23.3%	1.6%	0.1%