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THE ENVIRONMENTAL PROFILE OF ETHANOL DERIVED FROM SUGARCANE IN ECUADOR: A LIFE CYCLE ASSESSMENT INCLUDING THE EFFECT OF COGENERATION OF ELECTRICITY IN A SUGAR INDUSTRIAL COMPLEX

PROBLEM STATEMENT

Nowadays, there is a general scientific consensus that observed trends in global warming had been caused by the indiscriminate use of fossil fuels in human activities.

OBJECTIVE

Develop a life cycle inventory for Ecuadorian sugarcane and sugarcane-derived ethanol production to quantify its environmental performance considering the effect of electricity co-generation produced in the sugar industry complex (Table 1).

Table 1. System expansion scenarios for the co-generation stage

Scenario	Type of generation displaced
Average mix displacement	Average electricity mix
Marginal technology displacement	ICE operating on fuel oil
No displacement	Not applicable

PROPOSAL

The International Organisation for Standardisation (ISO) provides the LCA standards through the ISO 14040 and 14044. LCA methodology consists of four stages: goal and scope definition, inventory analysis, impact assessment, and interpretation (Figure 1).

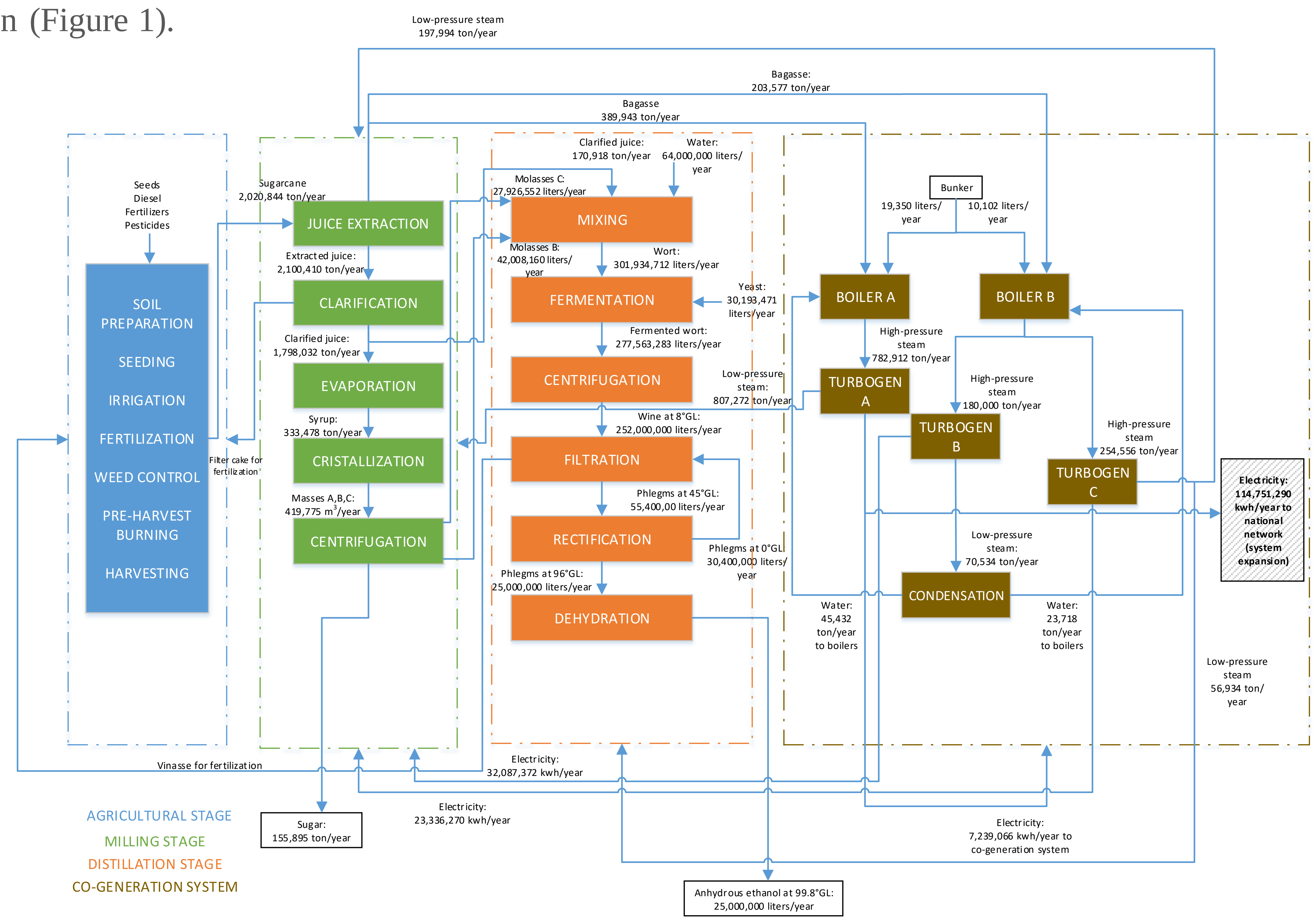
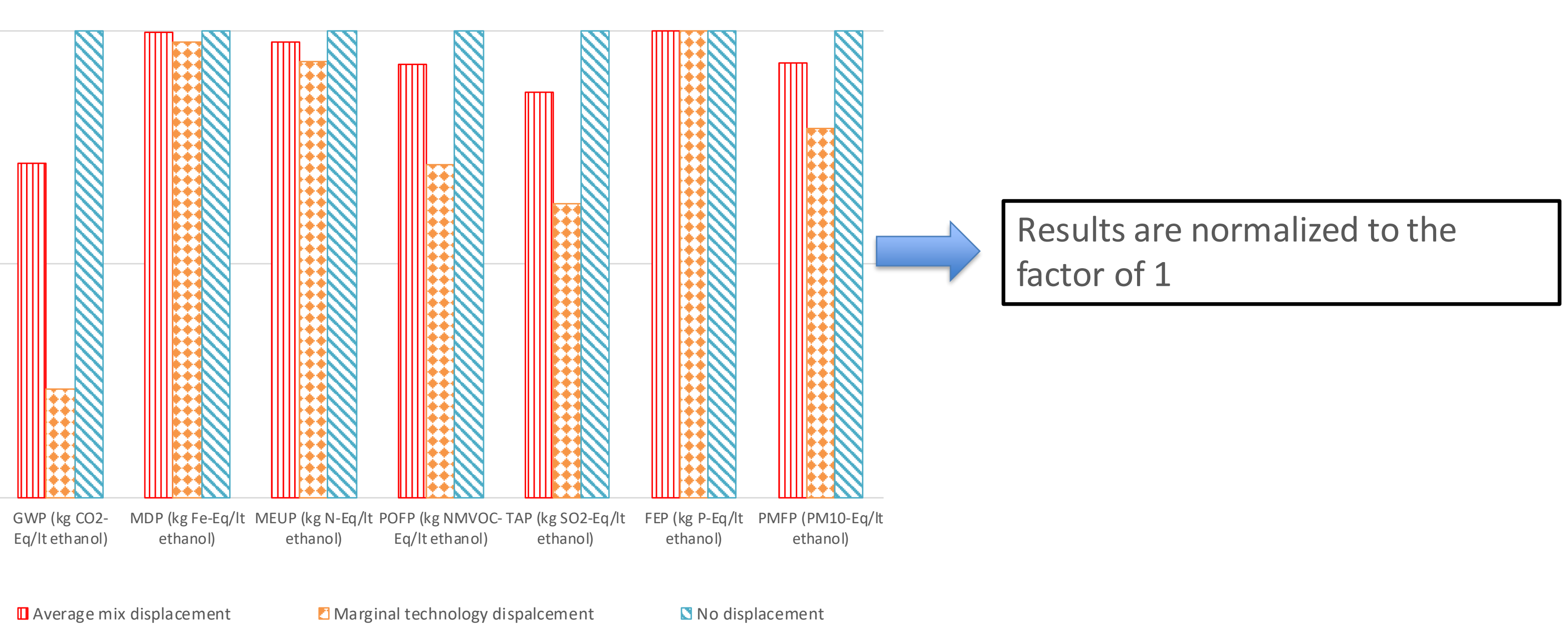


Figure 1. Anhydrous ethanol life cycle system boundaries and main product flows quantification for year 2018

RESULTS

The GWP impact generated at the farm gate level was reported as 53.6 kg of $CO_{2eq.}$ per sugarcane due to N_2O volatilization and diesel application in agricultural machinery. Considering the ethanol production level, the GWP impact was reported as 0.60 kg $CO_{2eq.}$/liter of ethanol (Table 2). Credits were received for displacing surplus electricity produced in the co-generation stage (Figure 2 and Table 2).



Results are normalized to the factor of 1

Figure 2. Comparison of LCA impacts at plant-gate for different system expansion scenarios.

Impact category	Agricultural	Milling	Distillation	Cogeneration	Total impact Indicator Result
	Impact Indicator Result	Impact Indicator Result	Impact Indicator Result	Impact Indicator Result	
GWP (kg CO2)	0.28582	0.0013	0.369	−0.05059	0.606
MDP (kg Fe)	0.00688	0.00089	0.0078	−0.0000048	0.01557
MEUP (kg N)	0.0018	0.00001	0.00206459	−0.00006459	0.00381
POFP (kg NMVOC)	0.00514	0.00249	0.01253	−0.00182	0.01834
TAP (kg SO2)	0.00499	0.0012	0.0098	−0.00071	0.01528
FEP (kg P)	0.0000928	0.0000372	0.00014	−0.00000031	0.00027
PMFP (kg PM)	0.00341	0.00083	0.00589	0.00006065	0.01019

Table 2. Impact categories in different stages to produce ethanol (FU = 1 L of ethanol).

CONCLUSIONS

- Scenarios where system expansion is applied, led to lower impact values compared to the scenario where no surplus electricity is displaced
- Sugarcane industrial sector should increase its co-generation capacity in order to embraces its own electricity demand.
- Companies should apply industrial symbiosis and circular economy strategies to produce lesser environmental loads within ethanol production chain.
- Sugarcane growers must optimize synthetic fertilizers application by implementing precision agriculture to guarantee greater sustainability