SUCRE
Sugarcane Renewable Electricity

SUSTAINABLE BIOELECTRICITY

The importance of quantifying impacts of bioelectricity production. Anticipating the impacts of bioelectricity production from sugarcane straw is a very important task when thinking about sustainable energy production. In the context of SUCRE Project, tailor made assessments were performed to accurately quantify the economic, environmental and social impacts of each conversion technology using the Virtual Sugarcane Biorefinery (VSB). This simulation framework integrates both agricultural and industrial models to anticipate the impacts of biorefineries on different sustainability aspects (Bonomi et al. 2016). VSB has been developed and updated over the last decade by the Brazilian Biorenewables National Laboratory (LNBR), that integrates the National Center for Research in Energy and Materials (CNPEM).

Lessons learned in SUCRE: the importance of an integrated assessment. In SUCRE Project, agricultural and industrial phases were assessed in an integrated model, considering the positive and negative aspects of the entire production chain. In the agricultural phase, the baling technology enables compacted straw to be recovered with low moisture. This technology has lower costs for larger quantities of straw recovered per hectare and longer transport distances. On the other hand, baling machineries can be associated with potential damage on both sugarcane ratoons and soil structure. For the integral harvesting technology, on the other hand, straw and stalks are harvested simultaneously and no additional operations are required. A benefit from this technology is the reduction on sugarcane stalk losses which, in turn, decrease integral straw cost. On the other hand, this technology reduces load density and straw has a higher moisture; consequently, it increases the transport cost. A lesson learned from this technology is that integral harvest has lower costs for shorter transport distances and smaller amounts of straw recovered per hectare.

In the industrial phase, straw recovered through bales goes through unbaling, sieving and chopping before being used as fuel. The straw collected through integral harvesting requires additional equipment to separate it from sugarcane stalks, such as Dry Cleaning System (DCS), which still presents low efficiency, affecting sugarcane milling capacity and efficiency. Straw, either recovered through bales or separated by DCS, has different ash content, moisture, density and particle size when compared to bagasse. Thus, straw use as fuel in boilers traditionally designed for bagasse is still limited due to difficulties on continuous feeding and operation.

Considering the positive and negative effects of straw on both agricultural and industrial phases, it is necessary to carry out an integrated assessment to reach a verdict on whether it is advantageous or not to recover straw, and on which route would be the most appropriate. Agricultural and industrial parameters must be considered to have a better understanding of how these parameters interact with each other and of the possible economic and environmental impacts for the selected route. Among the scenarios that were assessed in SUCRE Project, the answers related to economic viability of sugarcane straw bioelectricity varied a lot because they depended on many factors. Surely, the straw recovery cost has an important impact, however, many other factors such as industrial scale, previous industrial infrastructure, industrial efficiencies, electricity prices, business model and even the regulatory context can impact the decision-making process. Figure 1 shows an example of results of the incremental economic analysis with the range of straw recovery costs (US$ 9-45/ metric ton) and the minimum selling price of electricity (US$ 29-106/MWh) obtained in the assessed scenarios of SUCRE Project, considering an exchange rate of US$ = R$ 4.00.

Techno-economic analysis of integral harvest system to produce bioelectricity. The integral harvest system has also been assessed by Watanabe et al. (2020) and indicated economic feasible scenarios for this technology. This paper considered the current low availability of capital to invest in large-scale greenfield projects in Brazil, thus focusing on retrofit investments, i.e., those related to existing sugarcane mills aiming to increase electricity production with incremental investments. This paper explored the effects of industrial plant scale (from 2-8 million tonnes), straw transport distance (25-50 km), industrial operating period (season and offseason), Dry Cleaning System (DCS) efficiency (25%-55%) and electricity prices (US$ 60-150/MWh). The results of the study showed that straw recovery costs, using integral harvesting system, varied from US$ 12.40 to 14.16 per dry metric ton. Most of the integrated scenarios proved to be economically feasible even considering the innumerous challenges to achieve a cleaner electricity matrix in the country. In the sensitivity analysis carried out for the best incremental scenarios (operation during the offseason), internal rates of return (IRR) ranged from 35-69%, 44-83%, and 54-99% per year were achieved when considering mills with original crushing capacities of 2, 4 and 8 million tonnes of sugarcane per year. In the case of scenarios operating during the sugarcane harvest season, the IRRs were related to a range of

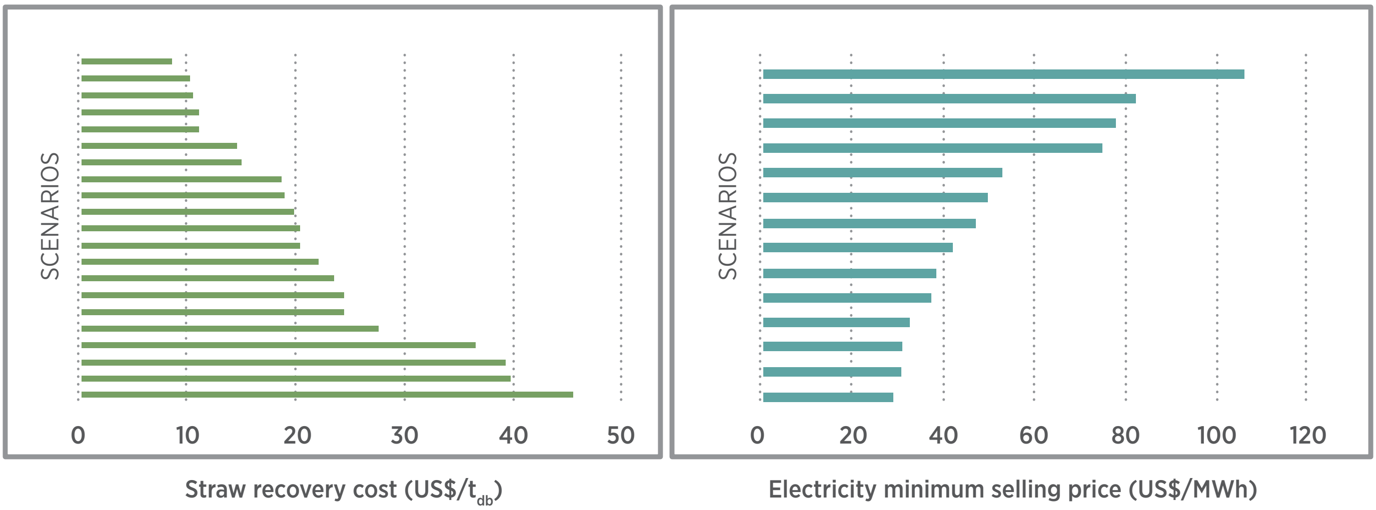

Figure 1. Example of results from partner mills in the context of SUCRE Project (tdb= metric ton of straw in dry basis).

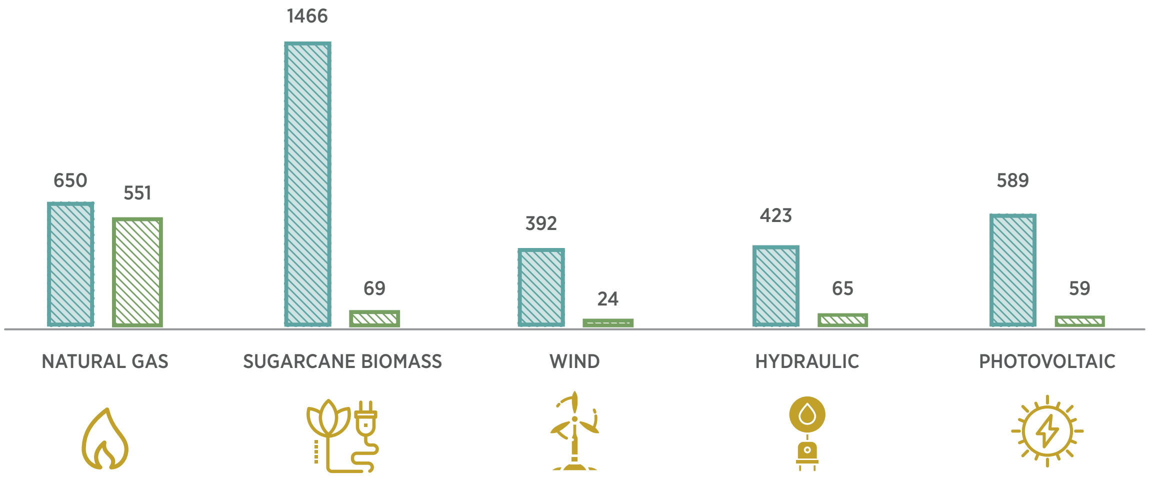

Figure 2. Comparison among renewable and fossil electricity sources in Brazil.

6-19%, 8-22% and 10-25% per year, respectively. The lower IRRs in the season are related to the need of incremental Capex to process the additional biomass. Also, this analysis ratifies that the economic feasibility increases as much as industrial scale increases. Also, Watanabe et al. (2020) highlighted that higher DCS efficiencies can improve the economic viability, although some non-linear effects could be observed under specific conditions of the industrial operation. From all studied variables, electricity price was one of the most sensitive parameters affecting the economic viability of straw recovery projects.

Techno-economic analysis and LCA of bioelectricity from baling harvest system. Sampaio et al. (2019) performed a techno-economic and life cycle assessment (LCA) of straw recovered through bale system and processed in an existing sugarcane mill that already exports electricity. By considering the synergies between the additional infrastructure and existing facility, two scenarios were proposed. Scenario 1 assumed that straw was processed in a cogeneration system with 10% idle capacity in the boilers and flexibility of condensing-extracting turbines to expand additional steam to generate electricity. Scenario 2 additionally considered partial operation of cogeneration system in the sugarcane offseason, which increased operation period in 65%. For both scenarios, the incremental investment was only the equipment directly related to straw processing (unbaling system, choppers, transportation belts, and others). Both scenarios were compared to the base case without straw recovery and processing. For all scenarios, main agricultural assumptions were yield of 75 tonnes of harvested stalks per hectare, fully mechanized harvest of green cane and average transport distance of 37 km. The sugarcane mill considered for this study processes 4 million tonnes of sugarcane and produces anhydrous ethanol, sugar and electricity. Based on these premises, 9 and 27% of the total straw produced in the field is recovered in Scenarios 1 and 2. Straw recovery costs varied between US$ 27 and 37 per metric ton, depending on the amount recovered per hectare. Electricity production increased 22 and 57%, respectively, compared to base case. The IRRs (27 and 31%, per year) were higher than the assumed discount rate (12%), which indicated the economic viability of both incremental projects. Economic performance showed a high dependence on electricity prices and that higher returns can be obtained from price peaks of the Brazilian short-term (spot) market at the expense of higher risk. Environmental assessment indicated that straw recovery and processing slightly decreases GHG emissions of biorefinery products. This is mainly because straw recovery increases the environmental benefit by increasing electricity surplus. Also, sugarcane ethanol and bioelectricity present significant environmental benefits compared with fossil sources of energy, such as gasoline and electricity from natural gas. Due to this mitigation potential of ethanol, it is expected that these biorefineries benefit from Brazilian program for biofuels incentive – RenovaBio, bringing environmental and economic benefits to the sugarcane sector.

Sugarcane Renewable Electricity in the context of Sustainable Development. SUCRE Project is closely related to the Sustainable Developments Goals (SDG), and presents benefits mainly to SDG 7: Affordable and Clean Energy and 13: Climate Action. The recovery of straw makes possible to increase electricity production with low GHG emissions and without expansion of sugarcane area (Sampaio et al, 2019; Souza et al, 2019). Most of recent sugarcane expansion (equivalent to more than 4 million hectares) happened over crops and pasture areas inside the Agroecological Sugarcane Zoning (ZAE) and has not contributed directly to deforestation; in addition, such expansion over pasture and annual crops favors the availability of water in hydrographic basins during dry season (Hernandes et al, 2018a, 2018b). Besides, there are still more than 20 million hectares available for sugarcane expansion within the ZAE, considering only the six states that most produce sugarcane in the Center-South of Brazil (Duft et al, in revision).

Potential GHG mitigation and positive socioeconomic effects. Sugarcane electricity generation in Brazil can increase from current 22 TWh to 104 TWh, only by recovering 50% of current produced straw and improving cogeneration system, without any additional area. This potential electricity could supply 78% of household electricity demand and mitigate 11% of Energy Sector emissions, considering bioelectricity replacing electricity from natural gas (SUCRE, 2020). Figure 2 shows the emission for each electricity source in Brazil, as well as their job creation potential for the operating phase. When comparing sugarcane biomass electricity with natural gas, a fossil energy source, sugarcane electricity can double the potential for job creation. When considering an increase in the electricity production to 104 TWh, about 120 thousand jobs would be created, instead of 53 thousand if the chosen source was the natural gas.