NOVEL USE OF RENEWABLE CHARCOAL TO REDUCE CO_2 EMISSIONS IN PELLETIZING PLANT*

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Abstract
The urgency of positive action in the fight against climate change and for more sustainable production has led Vallourec to renew its energy matrix by bringing in renewable charcoal waste for use in its pellet plant in Brazil. As part of an initiative supported by UN through UNDP and the Sustainable Steelmaking Project, Vallourec was a global pioneer in using charcoal as the main fuel in its iron ore pellet heat treatment furnaces. This paper reports and updates information on Vallourec's initiative, which successfully reduced emissions from iron ore pellet production at the Jeceaba-MG pellet plant in Brazil by 23,894 metric tons of CO_2e during the UNDP monitoring period (2018-2019) and by more than 200,000 metric tons of CO_2e overall, considering the start of implementation in January 2017 through the end of 2021. The improvement also brought a significant reduction in operating costs, resulting in a payback of the total investment in only 18 months.
Keywords: Charcoal; pelletizing; CO_2e; Brazil.

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1 INTRODUCTION

This paper reports and updates information on Vallourec's pioneering initiative that successfully reduced CO_2e emissions from iron ore pellet production at the Jeceaba-MG pellet plant in Brazil. The improvement also brought a significant reduction in operating costs and contributed to the company's target for reduction of emissions[1].

The urgency to drive positive action to combat climate change reinforces the global commitment to implement the necessary changes in steel production through cleaner routes[2]. The use of biomass has been intensified as an alternative to fossil fuels; either from materials recovered as residues or by-products, or through biomass produced in renewable and sustainable cycles[3][4][5].

Brazil, due to its large land area and high insolation rate [6], has great potential for the use of biomass cultivation to restore degraded land[7]. Sustainable and smart use of land and environmental resources for soil rehabilitation can bring great benefits, such as carbon fixation in the subsoil biome (fungal hyphae and roots), carbon fixation in the above-ground biomass plants (wood, stems, branches, and leaves)[8], besides the generation of jobs and income.

Vallourec's energy matrix is already considered one of the most environmentally friendly in the Brazilian and global steel industry, as the company obtains most part of its electrical energy from hydroelectric plants, has good management of electricity consumption and is certified to the ISO 50.001 standard [9]. Excess gasses from the blast furnace are also recycled as much as possible to reduce natural gas consumption in the steelmaking shop and tube mill of the Jeceaba integrated plant. By managing its processes responsibly, Vallourec reuses, recycles and disposes of almost all the by-products of its production, thus ensuring a reduction in emissions in the production chain by reducing the use of raw materials.

A key point for this green energy matrix is the use of renewable charcoal from Vallourec’s own forests to produce green pig iron in steel production. Vallourec also develops its own *Eucalyptus* clones for wood and biological resources to avoid pests.

Vallourec has applied the in-house pelletizing concept at this mill, where a pelletizing plant has been installed within the steel plant to supply its own blast furnaces. The guidelines are: Quality, customer focus and optimized costs [1].

Being inside of the steel plant, this pelletizing plant was designed as a recycler, just like sintering plants, within the technical limits and pellet quality specification. This concept was elaborated and defined to reuse the main mill residues containing oxidized Fe, carbon and flux. In this concept, the fine charcoal, previously considered as a by-product to be properly disposed of, becomes an interesting fuel to be used in the burners of the heat treatment furnaces and also in the pellets mixed with the iron ore. Vallourec has continuously developed this concept. This article summarizes the progress made with charcoal.

2 DEVELOPMENT

2.1 Industrial installation and process

The process, shown in Figure 1, begins with the continuous cultivation of *Eucalyptus* trees for 7 years as a renewable forest.

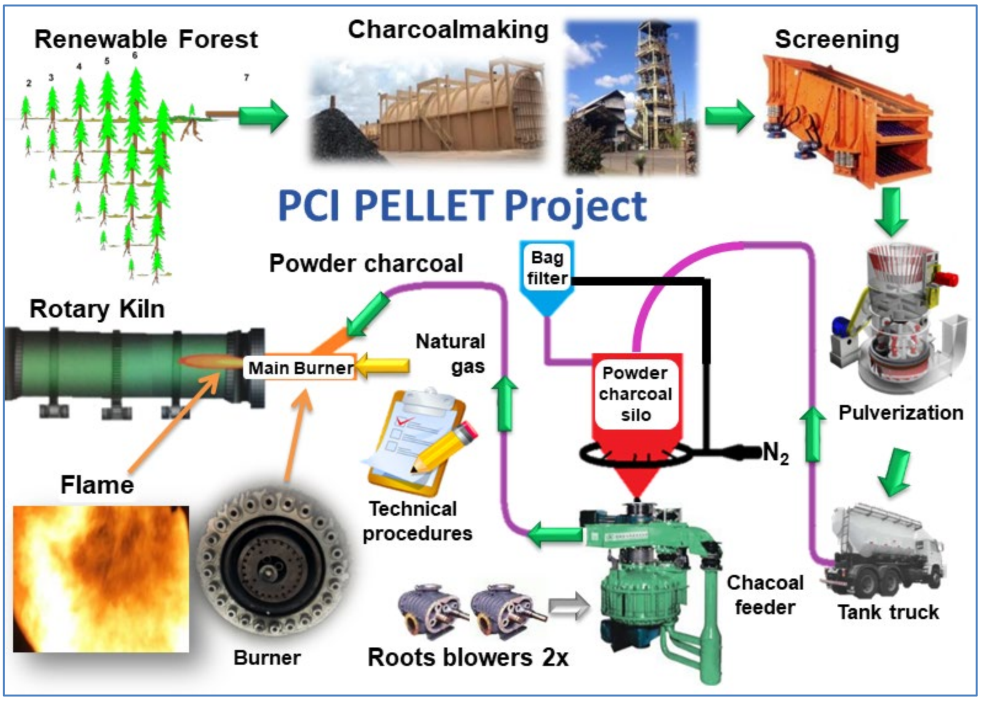

Figure 1. Process flowchart of charcoal injection in rotary kiln.

During this time, the trees sequester CO_2 from the atmosphere. In the 7th year, the dimensions are sufficient to harvest and perform pyrolysis of the wood. After the drying period of the wood in the field, the charcoal making begins in the furnaces.
The charcoal produced is cooled and then transported in closed trucks to the Jeceaba plant. Once at the plant, the raw charcoal is dumped into the silo by a truck. Processing begins with a 150mm screen to remove the uncharred wood. Then the charcoal is screened to separate the coarse, medium and fine fractions, i.e. the fraction that passes 10mm. The coarse and medium fractions are put into the upper part of the blast furnace, while the fine material is pulverized in a vertical mill. After pulverization, the material can be injected into the bottom part of the blast furnace or transported by tanker trucks to the pelletizing plant for injection in to the main burner.
Once at the pelletizing plant, the tanker is connected to the receiving pipes for the powder charcoal and to compressed air lines that pressurize the tank so that the charcoal can be unloaded into the 60 m³ storage silo, which holds about 20 tons.

Figure 2. Solid pulverized fuel feeding system.

A solid fuel feeder (Figure 2) with a capacity of up to 4.8 tons/hour, manufactured by Hefei Cement Research Design Institute in China, is used to control the injection rate. This feeder allows varying the rotation speed of its internal rotor to adjust the solid fuel rate in volumetric or mass mode with instantaneous weight measurement in the feeder.

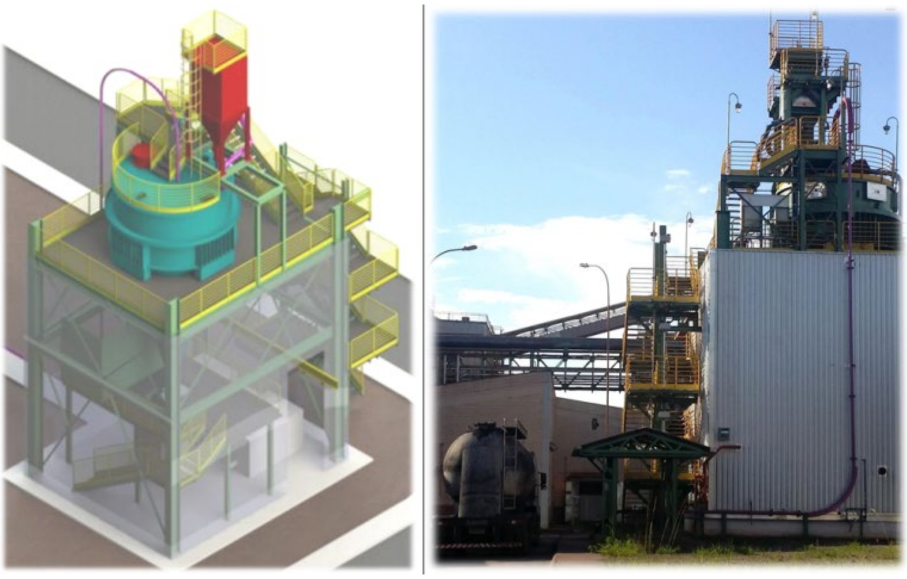

Figure 3. Design and final installation of the pulverized charcoal injection system.

To ensure the safety of the system against fire, the silo was equipped with thermocouples, explosion-proof diaphragms, CO (carbon monoxide) gas detector, pulsed nitrogen injection for fluidization, and nitrogen injection through an automatic control valve for fire suppression. The building housing the silo (see Figure 3) also has a fire detection and alarm system with automatic water sprinklers. The building's safety is based on the American standards NFPA and the technical instructions (IT) of the Fire Department of Minas Gerais-Brazil with evaluation and approval from FM-GLOBAL, an American insurance company specialized in loss prevention and risk insurance.

2.2 Fuel Scenario Analysis

During the initial development phase, alternatives to the original 100% natural gas scenario were investigated. Powdered charcoal, mineral coal, petroleum coke, and a blend of charcoal and petroleum coke were evaluated.
The risk assessment looked at the following criteria: cost reduction, logistics, availability of each fuel, industrial complexity in implementation, changes in pellet quality, and environmental impact (see Figure 4).

Installations	Scenarios A	Scenarios B	New Purchases?
Building	X	X	YES
Grinding System		X	NO
Silo	X	X	NO
Injection System	X	X	NO
CAPEX (MR$)	100%	175%	-

Fuel	Cost (R$/Mcal)
Natural Gas	100%
Charcoal	33%
Mineral Coal	50%
Petroleum Coke	50%

Risks	
(green)	Low
(yellow)	Medium
(orange)	High
(red)	Very high

Scenarios		Natural Gas Original Scenario A	Natural Gas Original Scenario B	Charcoal A	Charcoal B	Mineral Coal A	Mineral Coal B	Petroleum Coke A	Petroleum Coke B	Charcoal + Petroleum coke A	Charcoal + Petroleum coke B
RISKS	Fuel Cost	Very high	Very high	Low	Low	High	Medium	Medium	Medium	Low	Low
	Logistics	Low	Low	Medium	Medium	High	High	Medium	Low	Medium	Low
	Availability	Low	Low	Low	Low	Medium	Medium	High	High	Medium	Medium
	Industrial complexity	Low	Low	Low	Low	High	High	Medium	Low	High	High
	Pellet Quality	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
	Environmental	Medium	Medium	Low	Low	High	High	Medium	Medium	Medium	Medium

Figure 4. Comparison of possible scenarios for fuel switching

Charcoal scenario was the most favorable in general evaluation. It presented the lowest costs, low risk in availability, and no issues for industrial complexity, pellet quality and environmental impact. As Vallourec already has a grinding system for charcoal for use into the blast furnace and this system was operating below full capacity due to lack of demand, no additional investment was needed for a new grinding system. For comparison, if the fuel chosen was different solid fuel or a solid fuel mix it will be necessary to have a new separate system for its grinding.
The grinding station now meets the demands of both areas: blast furnace and pelletizing plant, using also the same specification: at least 80% of powder mass -0,074mm, at least 67% fix carbon, inert matter content less than 7%, moisture content less than 3%. During the grinding, hot gas is used for drying the solid fuel and this hot gas comes from burning and recycling waste gas from blast furnace, avoiding use of fossil natural gas. This waste gas is carbon neutral because Vallourec's blast furnace uses renewable charcoal as fuel.

2.3 Preliminary tests

Between the end of 2015 and the beginning of 2016, preliminary tests were planned and carried out [1] to verify the technical feasibility and safety of feeding pulverized charcoal into the current burner of the rotary kiln of Vallourec's pellet plant. It was proved that charcoal powder is feasible for using into the rotary kiln burner and pellet quality remained the same from original scenario with natural gas [1].

2.4 Technical Procedures definition and evolution

Much of development work was to previously define the technical procedures for operation with pulverized charcoal and update and adapt them with plant team during the advance of the learning curve since 2017 to end of 2019 (see figure 5). From 2020 onwards, small incremental improvements were done. But the key parameters and operation standards were already set in running in routine operation.

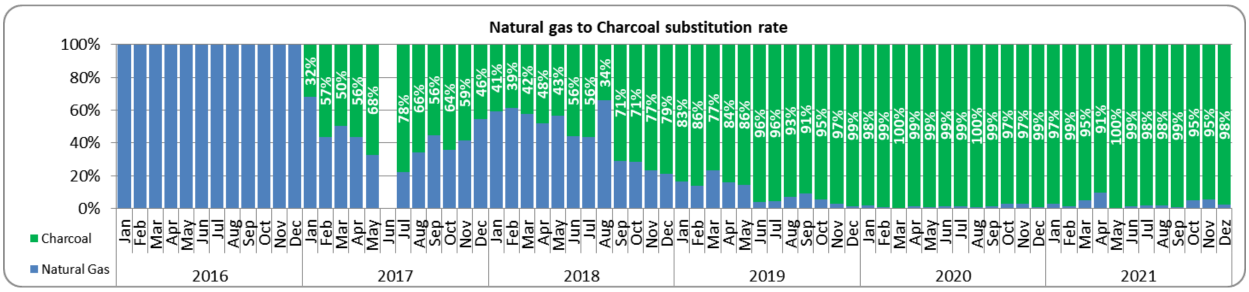

Figure 5. Learning curve showing increase in Charcoal using rate

Here are listed some of the key points of development to needed to ensure technical availability of using charcoal powder as main fuel:

- Adjustment of external / internal combustion air distribution at the burner
- Adjustment of flame length and width to avoid refractory overheating
- Controlled addition of fluxes to avoid deposit formation inside rotary kiln
- Online 360° thermal monitoring of rotary kiln shell for deposit formation
- Adjustment of flame to preventively attack small deposits to avoid their growing
- Control of the grain sizing of the pulverized charcoal
- Check and avoid contamination of charcoal fines with dirt (soil)
- Inspection and adjustment of pulverization mill to remove contamination and ashes
- Control of pressure inside storage silo during charcoal transfer from trucks
- Parameterization of charcoal feeding equipment for automatic control
- Lowering of kiln thermal profile to keep charcoal heating during small outages
- Maintenance plans for equipment in operation, in small stoppages, in big outages
- Detailing of fire prevention and firefighting measures validated with FM Global
- Safety procedures were detailed and all involved staff was trained

The main issue to be solved was the abnormal generation of material deposits inside of rotary kiln stick to refractory bricks. Firstly this abnormal formation of deposits was attributed to charcoal, but it could be demonstrated to plant staff that other process disturbances out of control limits were the real cause. After setting new control limits and improving its monitoring and quick actions to keep the KPI under control, then deposit formation came back to normal and increasing percentages of charcoal could be used without affecting the plant productivity.

2.5 Methodology and Results in reduction of CO_2e emissions

Reducing the environmental impact of Vallourec's activities was a key motivation of this project and a result achieved, as can be seen on Figure 6.

In 2018, a selection process was conducted for projects with a positive impact on reducing CO_2e emissions that involve the use of renewable charcoal in the steel industry. The selection was carried out by the Sustainable Steelmaking Project (*Projeto Siderurgia Sustentável*), an initiative of UN by the United Nations Development Program (UNDP). Vallourec's project was presented and selected for institutional support and financial assistance of 1 million Reais at that time. This was offered with restriction that the company must have already invested at least three times the grant offered. In fact, Vallourec had already invested more than 6 times this grant in this project by that time. The amount received was used to hire a consultant specialized in pulverized charcoal injection systems and to make the modifications he proposed to the installed plant in order to increase the stability of the pulverized charcoal fed to the burner. Once the technical problems of the plant were solved and the stability of the solid fuel feeding was improved, it was possible to increase the charcoal injection rate and thus the substitution of natural gas, as can be seen in Figure 5.

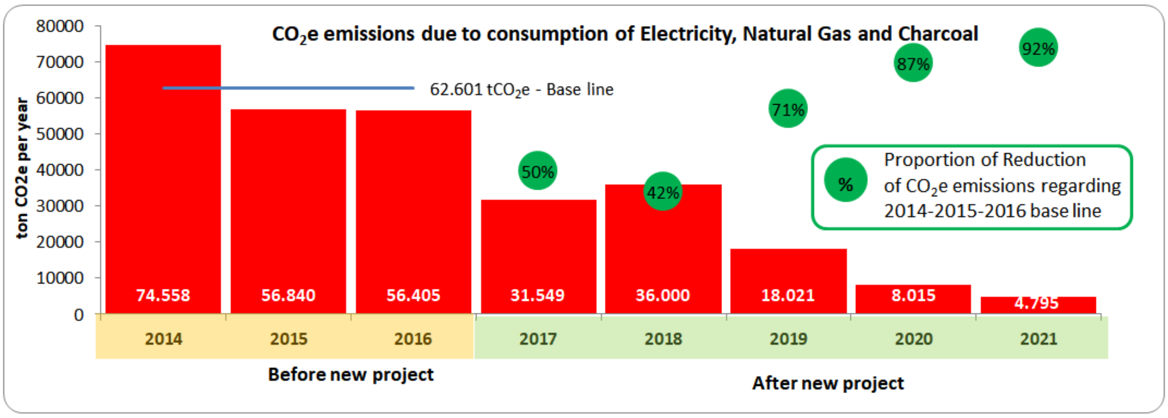

Figure 6. Evolution of reducing CO_2e emissions before and after the improvement

As part of the development of the Sustainable Steelmaking project, participating companies presented the methods they already use to measure, report and verify their actions to reduce CO_2e emissions. Vallourec presented its calculation table in accordance with the AMS-III.AS methodology: switch from fossil fuel to biomass in existing manufacturing facilities for non-energy applications --- Version 2.0 of the UNFCCC for small scale emissions scopes.
The technical proposal foresaw a reduction of 6,136.75 tons of CO_2e by adding the results of 2018 and 2019.
After the contract was signed, with a minor revision to the measurement methodology, the target was revised to 5,054 tons CO_2e by adding the 2018/2019 targeted results. The reduction in the forecast was due to the inclusion of methane generated during charring associated with the use of charcoal from suppliers outside Vallourec in accordance with the AMS-III-K methodology.
The project also aimed, as required by the public notice, for emission reductions to exceed 270 kg CO_2e/ton of charcoal.

Purchases of the byproduct charcoal fines from third-party independent pig iron producers are limited to companies and subcontractors that could demonstrate the legal origin of the wood and meet their labor, social security, and tax obligations, as well as demonstrate good practices in handling the grinding in order to avoid or minimize contamination.
The improved charcoal injection system now can consume all internal surplus or charcoal fines (not consumed by blast furnace) and also the additional amount purchased from third-party suppliers. After September 2021, the internal equilibrium of generation and consumption of charcoal fines made it possible to stop purchasing charcoal fines from outside of Vallourec production limits.
The methodology AMS-III-AS instructs how to calculate the baseline for comparison. It instructs to account for CO_2e emissions due to original fuel scenario summed with emissions calculated for electrical energy consumption for three years before of the beginning of the new project for substitution of fossil fuel to renewable fuel. In this case, those years were 2014, 2015 and 2016. For reference, Vallourec's pelletizing plant was started and operational since January 2013 and was passing through ramp up phase, increasing the production capacity until 2018 when full capacity of 1,360,000 ton of iron ore pellets per year. Even with increasing production one can see from Figure 6 that absolute values of CO_2e emissions continuously decreased as a general trend.

The support from the Sustainable Steelmaking project helped to drive the new action and investment plan beyond Vallourec's original project, and the results achieved exceeded expectations. The project aimed to replace 79% of natural gas with charcoal, and a substitution of more than 92% in monthly average and 100% in operational routine was achieved. The emission reduction under the original technical proposal for the Sustainable Steelmaking Project was 6,136.75 tons of CO_2e in 2018-2019, but by July/2019 the reduction was equivalent to 23,894 tons of CO_2e, almost 300% more than the original target.

By 2022, Vallourec project achieved a total reduction of more than 200,000 tons of CO_2e, taking into account the project since its start in 2017, the results measured until December/2021; against 2014-2016 baseline.

As for the specific reduction target of 270 $kgCO_2e$/ton of charcoal, it should be noted that taking into account the emission reduction measured with the support of the Sustainable Steelmaking project and the additional charcoal consumed under the project for the original project tracking period 2018-2019, the result was: 984 $kgCO_2e$ / ton of charcoal.

In addition to the excellent environmental results, we have found that the total investment has been recouped in just 18 months through the savings generated by the project, and that the ratio of the expected net present value after 10 years of the project to the total investment exceeds 16 times.

3 CONCLUSION

Through the application of UNFCCC methodologies, pre-testing, plant engineering, and teamwork between the disciplines of process control, automation, and operations, external consultants, and with UNDP support, the project was brought to fruition. This is reflected in a significant reduction in CO_2e emissions and in financial values that are significantly better than the original planning.

Renewable pulverized charcoal was established in the operational routine as the main fuel in Vallourec's pelletizing plant. This initiative was considered a global pioneer in the use of this fuel as the main fuel in Grate-Kiln, as well as the iron ore pelletizing plant with the lowest specific environmental impact in terms of greenhouse gasses among the plants installed to date.

The environmental benefits, cost reduction, operational stability and process control justify sustainability of good results and routine standards.

Vallourec, in line with its beliefs and values, acts as a protagonist and pioneer, maintaining its vision to drive the use of renewable fuels to produce ever more sustainable seamless premium pellets and pipes.

Acknowledgments

The key for the further development of this project and the sustainability of the results was the recognition by the United Nations Development Program (UNDP) and the Brazilian government as part of the Sustainable Steelmaking Project.

This program has been working since its inception to establish a technical and normative framework in the government sector to support and promote projects aimed at reducing emissions through the planting of renewable energy forests, forestry improvement, charcoal production and the use of charcoal in industrial applications as a substitute for fossil fuels.

Obtaining the Sustainable Steelmaking Project's grant and institutional support to implement and pay for the improvements needed to solve the technical difficulties was critical to the project's success.

The good practices identified by the Sustainable Steelmaking Project in this project were recorded and systematized to share with other companies so that they can be implemented and help meet the Brazilian government's commitment to global emissions reduction.

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