THE INCORPORATION OF BIOGAS, BIOMETHANE, AND LOW-CARBON HYDROGEN IN TRANSPORTATION AS A PATH TO ENABLE THE ENERGY TRANSITION IN THE STATE OF SÃO PAULO

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ABSTRACT

Why is the State of São Paulo (SSP) betting on biogas, biomethane, and low-carbon hydrogen as alternatives for reducing greenhouse gas emissions? This research is based on analyzing the main public policy instruments of SSP that outline long-term actions for the state to meet the international agreements it is a signatory to. The conclusion highlights that this strategy is justified by the potential to leverage the economic power and established production and distribution infrastructure of the sugar-energy sector and the potential regarding the disposal of its solid waste. The incorporation of biogas, biomethane, and hydrogen is expected to serve as alternative sources to fossil fuels, reinforcing the need for a combination of various solutions to advance the decarbonization of the transportation sector.

Keywords: Energy Matrix, Bioenergy, Biofuels, Decarbonization, Sustainability.

INTRODUCTION

Aligned with United Nations campaigns, the State of São Paulo (SSP) developed the Climate Action Plan 2050 (PAC 2050) [1] and the State Energy Plan 2050 (PEE 2050) [2], key documents that guide and aim to align decarbonization actions through the adoption of more sustainable technologies and practices.

According to the Energy Balance of the State of SSP [3], the energy matrix is mostly renewable (57.3%), with emphasis on sugarcane derivatives and hydroelectricity, but still relies on fossil fuels (42.7%), mainly oil. Projections for 2050 indicate an increase in the share of renewables, particularly in bioelectricity, biofuels, and low-carbon hydrogen. In the power sector, solar and wind generation are expected to grow, while in transportation, electrification and the use of biofuels will be crucial.

The aim of this article is to understand why the SSP government has strongly advocated its commitment on biomethane, and also on biogas and low-carbon hydrogen (B2H) as alternatives for diversifying its energy matrix on both the supply and demand sides, based on the scenario of mitigating greenhouse gas (GHG) emissions by 2050.

Biomethane has a production potential in SSP of 36 million Nm^3/day, more than double the total consumption of the entire state [4]. Biogas has the potential to meet 40% of the electricity demand and 70% of the diesel consumption in Brazil. Meanwhile low-carbon hydrogen (LCH) is projected to growth in the state's energy matrix, mainly in the transportation and industry sectors.

MATERIALS AND METHODS

The answer to the research question was provided through a critical analysis of the main documents for the formulation of public policies and the promotion of technologies that support the energy transition (ET), such as: [1], [2], and [3], as well as by consulting legislation, decrees, acts, etc. produced by the State Secretariat for the Environment Infrastructure, and Logistics and by the Legislative Assembly of SSP.

This is not an exhaustive analysis, but rather a survey and selection of proposals and actions related to the diversification of the energy matrix, aimed at identifying the rationales and commitments of the SSP with these developments.

RESULTS AND DISCUSSION

The SSP accounts for 21.8% of Brazil's total population, with about 44.4 million inhabitants [5]. It ranks as the 4th state in the country for total emissions. The state's energy matrix includes 57.3% renewable sources, compared to 48% in Brazil and 14% globally, with emphasis on sugarcane biomass and hydroelectric power [3].

In the case of biomass, SSP is the largest producer of ethanol in the country from sugarcane, with a production of 12 million m^3 (39%). According to [3], sugarcane derivatives (alcohol and bagasse) represented 33.2% of the matrix in 2022. Bagasse, a byproduct of sugar and ethanol production, is an important energy source for the industrial sector and electricity generation. furthermore, SSP has the potential to produce 36 million Nm^3/d of biogas, which is more than double the total consumption of the entire state.

The state's projected energy matrix for 2050, under a mitigation scenario and based on the year 2021, aims for a 19% reduction in petroleum derivatives, a 16% increase in electricity, the maintenance of 14% in biomass, and a 3% increase in natural gas. The share of fossil diesel in the fuel mix is expected to decrease by 41% by 2050, and the demand for gasoline C (a blend of gasoline and anhydrous ethanol) is projected to be reduced by over 99% by 2050 [2].

The electrification of the transportation sector, the greater use of biofuels (biodiesel and green diesel), and the introduction of methane and hydrogen in heavy fleets are expected to account for the reduced share of fossil fuels. Indeed, an increase in the electricity demand is projected, expected to reach 35 TWh by 2050, driven by transportation and industry, an increase that is also expected for LCH [2].

The interaction between B2H is synergistic and important for the ET. Biogas, produced by the anaerobic decomposition of organic matter, contains methane (CH_4) and carbon dioxide (CO_2). When purified, biogas is converted into biomethane, wich is equivalent to natural gas and can be used as fuel or for power generation.

LCH can be produced through flexible methods, including water electrolysis using renewable energy, natural gas reforming with carbon capture and storage technologies, natural gas pyrolysis, or catalytic reforming, gasification, or anaerobic digestion of biomass or biofuels. Biomethane can also be steam reforming to produce hydrogen, where it reacts with steam in the presence of a catalyst to generate hydrogen and carbon monoxide (CO).

Biogas produced from rural and urban waste can be purified to obtain biomethane. Biomethane can be combined with LCH to form biohythane, a biofuel with higher energy power and a lower carbon footprint. The production of biogas and biomethane from waste contributes to the circular economy and complements the production of LCH.

Numerous initiatives, particularly research and development (R&D) projects and investments, are already underway in the SSP to achieve these goals. By 2024, SSP has around 21 projects focused on ET with planned investments of approximately R$ 17 billion, and the creation of over 4,500 jobs. These projects encompass biogas production, solar energy generation, expansion of the ethanol transportation network, development of hybrid and electric vehicles, hydrogen-powered trucks, energy generation from waste, and energy efficiency improvements, among others, all aimed at advancing a progressively cleaner energy matrix [3].

The potential for biogas production from the anaerobic digestion of organic waste, such as those from the sugarcane industry (vinasse, sugarcane bagasse), agriculture, sanitation, and solid waste in SSP is 1.3 billion m^3 per year, accounting for 35% of national production. In 2020, the state generated about 16.5 million tons of urban solid waste [4].

The sugar-energy sector in SSP can generate up to 57.6 million m^3 of biogas per day. There was a 21% increase in the number of biogas plants and 27% rise in production compared to 2021. In 2023, the sugarcane harvest represented 44% of the state's agricultural production, generating about R$ 59.21 billion. furthermore, SSP is responsible for 61.8% of sugar production in Brazil.

In terms of public policy proposals for biogas and biomethane in SSP, notable regulations include: Decree No. 58.659/2012, which established the Biogas and Biomethane Program with mandatory distribution percentage and created the Biogas and Biomethane Management Committee; the Bioenergy Program (2015), which promotes energy generation from biomass and includes initiatives and incentives for biogas and biomethane production; Resolution No. 744/2017, which regulates the injection of biomethane into the gas grid; Decree No. 67.286/2022, wich expands tax benefits for bioenergy, including biogas and biomethane; and the Joint Resolution of the Secretariat for the Environment and Agriculture (2024) which simplifies environmental licensing for projects using biogas and biomethane.

Regarding the LCH, SSP currently does not have commercial production, but has ongoing projects. Additionally, there are no established public policies specifically for LCH, however, it is identified as a key area of focus and appears in various Plans and

Decrees, such as [1] and [2], as well in Law Project No. 1510/2023 which proposes tax incentives for hydrogen-powered or hybrid vehicles that using ethanol.

CONCLUSION

Recapturing the research question, it is possible to point out that the interaction between B2H offers a promising path for ET in SSP, with the potential to reduce emissions through energy matrix diversification. Indeed, the plans aimed at promoting the ET in SSP include targets for the development and integration of these options as a mean of boosting sustainable development. However, overcoming the challenges of infrastructure, investment, and regulation is crucial for these technologies to reach their full potential.

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