UNIVERSIDADE FEDERAL DE SANTA CATARINA

Estimating Green Hydrogen production in Brazil

UNIVERSIDADE FEDERAL DO CEARÁ

Fraunhofer ISI

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Abstract

Green Hydrogen (GH2), derived from electrolysis using various Renewable Energy (RE) sources, is emerging as a pivotal element in the ongoing energy transition. Brazil, with its abundant RE potential, stands at the forefront of numerous nations in this regard. However, uncertainties loom over the outlook for GH2 production, largely due to its current high levelized cost and supply chain intricacies. This paper aims to estimate Brazil's potential for GH2 production and exports by 2050. Utilizing a System Dynamics model, supported by data from official reports, on-site visits to a prospective GH2 hub, and relevant literature, we project the country's RE capacity to expand to 457GW by 2050. This growth, inclusive of both baseline (332GW) and GH2-driven (125GW) increments, is expected to yield annual GH2 production ranging from 2 to 20 million tons. To mitigate potential energy deficits, achieving an electrolysis (EL) capacity of 170GW by 2050 is imperative, necessitating the expedited deployment of RE, notably offshore wind power. The model underscores the necessity of refining public policies concerning GH2, particularly concerning export strategies. By addressing prevailing challenges and strategically bolstering RE infrastructure, Brazil can assert itself as a key player in the global green hydrogen market.

Introduction

Green hydrogen (GH2) is vital for decarbonizing industries and enhancing energy security. The EU aims to import large amounts of GH2 by 2030, with Germany as a key player. Brazil has significant potential due to its clean energy infrastructure and resources.

However, project delays, market uncertainties, and regulatory hurdles pose challenges. This paper aims to estimate Brazil's GH2 production and export capacity by 2050 using a system dynamics model that considers renewable energy capacity, electrolyzer capacity, and GH2 production dynamics, accounting for constraints, delays, and learning effects.

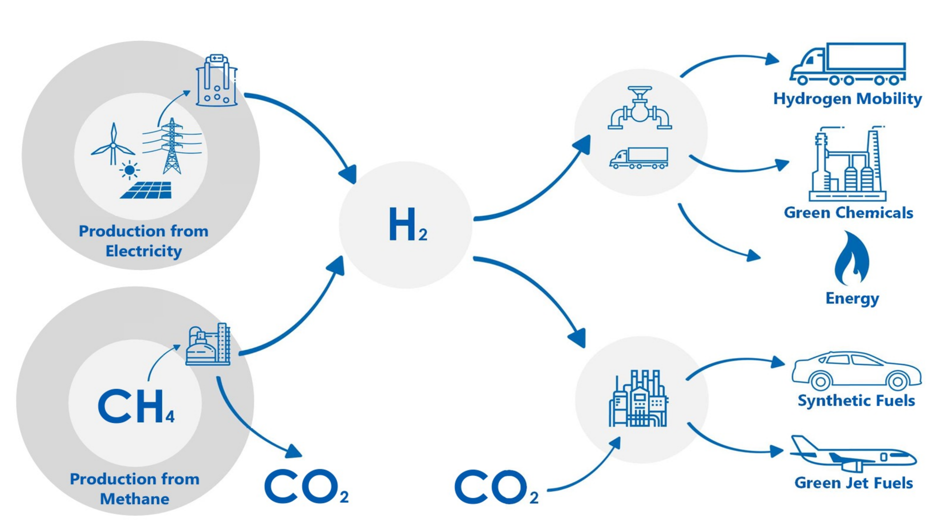

Figure 1. GH2 Value Chain. Source: [1]

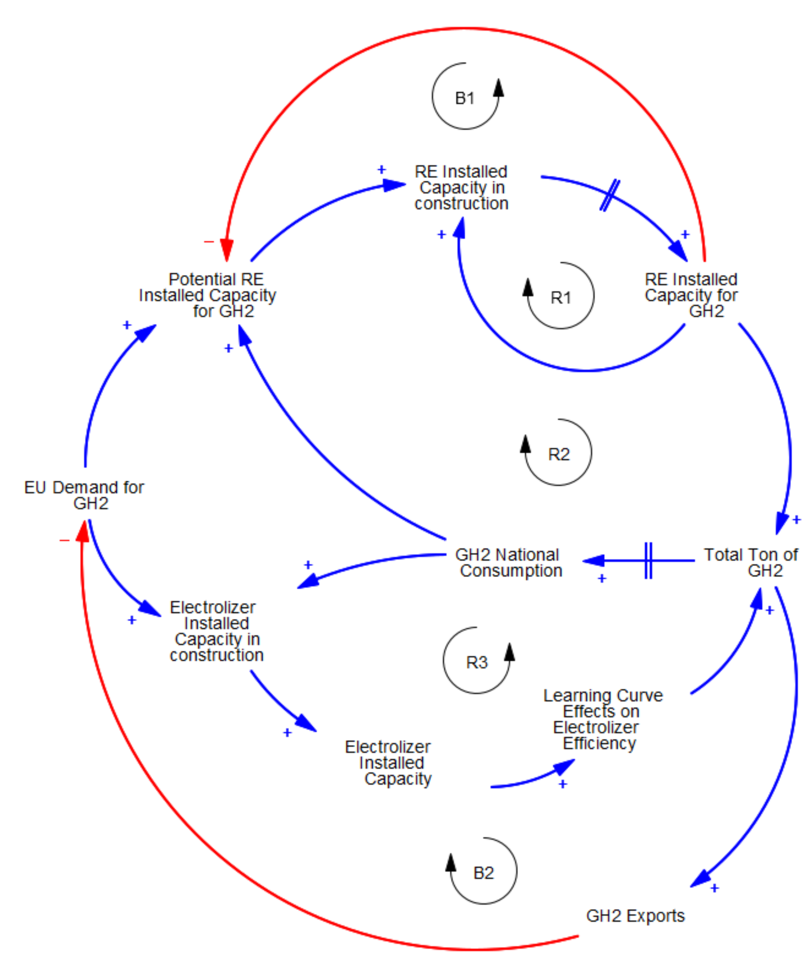

Figure 2. CLD for GH2 production in Brazil

Methods and Materials

Step 1.	A – get acquainted with the system and the problem
Step 2.	B – be specific about the dynamic problem
Step 3.	C – construct the stock and flow model
Step 4.	D – Draw the causal loop diagram
Step 5.	E – Estimate model parameters
Step 6.	R – Run the model to get the reference mode
Step 7.	S – Conduct sensitivity tests
Step 8.	T – Conduct policy tests

We followed Ford (2009) modeling process. Source: [2]

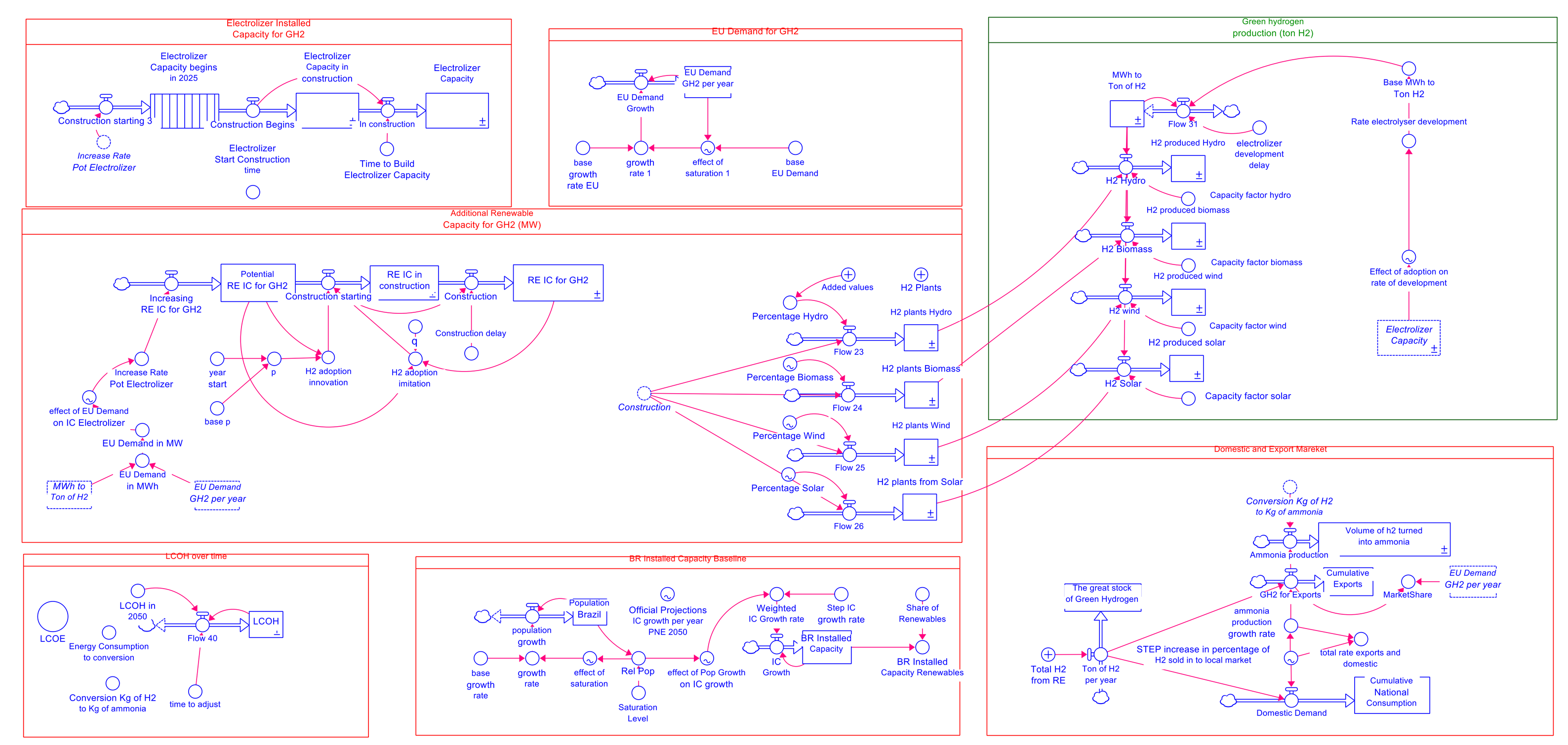

Figure 3. Stock and Flow model for GH2 production in Brazil

Results (1 of 2)

Our model accurately follows the trend from this official report and estimates between 313 and 344 GW by 2050, without additional capacities from the GH2 production chain, as shown in Figure 4a and 4b.

In other words, our model estimates a total RE installed capacity of 457GW by 2050 (versus 438GW of official estimations) by supplementing capacity above the baseline and therefore aligning numerically with the PNE2050 estimations, see Figure 4c.

With respect to total installed capacity, international reports, such as McKinsey's [3], depict higher figures, projecting a total installed capacity of 396GW by 2040 (our model estimates 303GW by 2040 and 516GW by 2050), as depicted in Figure 4d.

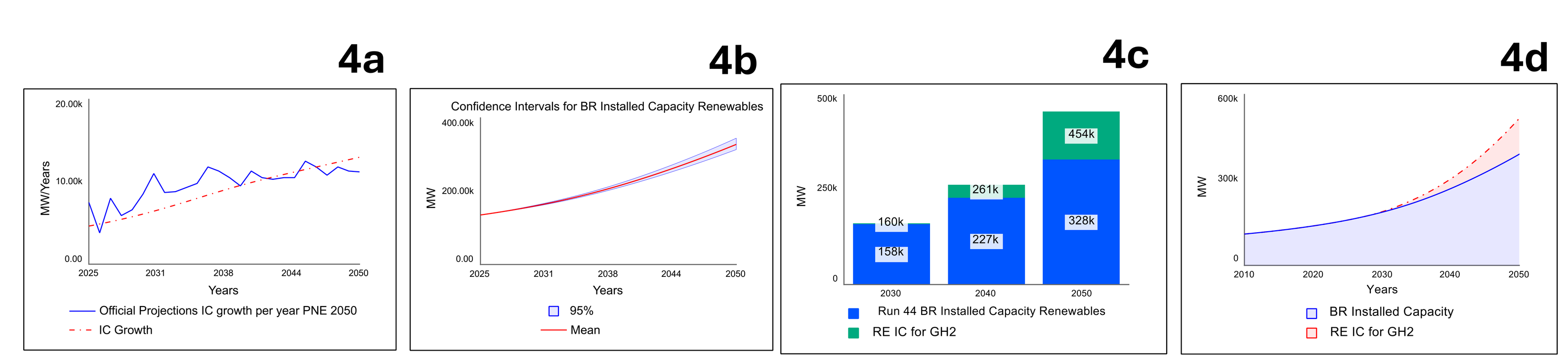

Figure 4. Baseline Scenario for RE Installed Capacity

Results (2 of 2)

Our model indicates that the installed capacity of Electrolyzers is anticipated to exhibit linear growth rather than exponential, projecting a range between 133GW and 201GW by 2050, as illustrated in Figure 5a. RE installed capacity is projected on Figure 5b.

GH2 production demonstrates more of an exponential growth trajectory, primarily driven by technological advancements, as depicted in Figure 5c.

Regarding the international market, our baseline scenario projects approximately 3 million tons per year by 2040 and 12 million tons by 2050, in line with other reports such as [3], which estimates between 2 to 4 million tons per year by 2040. Conversely, the domestic market could be primarily propelled by trucking, green steel, and other energy-intensive industries, potentially reaching 695 thousand tons per year by 2040 and 4.17 million tons per year by 2050 (refer to Figure 5d)

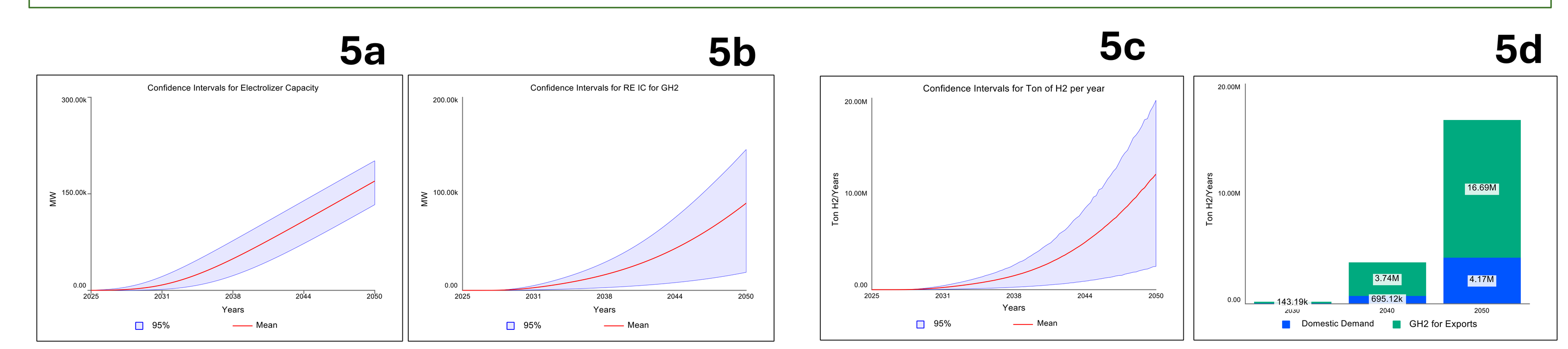

Figure 5. Sensitivity Results for GH2

Still in the export market, ammonia emerges as a prime candidate for transporting GH2 over vast distances due to its high energy density, low cost, and established global infrastructure for handling and distribution [4].

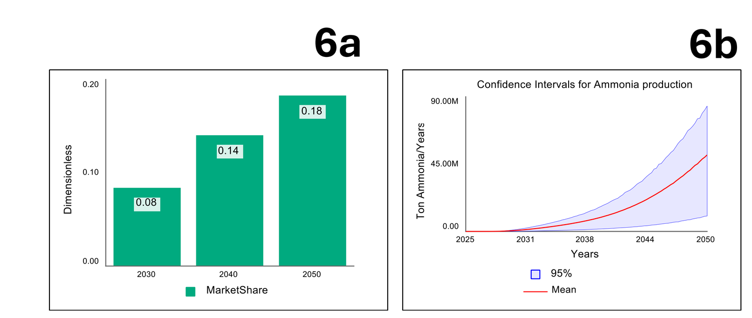

Figure 6. Ammonia Production

Our model estimates between 2 to 20 MTon of Ammonia per year for export only (Figure 6a), reaching 14% market share of the European Union demand by 2040 (Figure 6b).

Conclusions

This paper is the first system dynamics-based model that is built to understand the GH2 market in Brazil. Even though the current literature stresses the economic, technological and other barriers for producing GH2 in Brazil, there is little work on modeling the GH2 value chain. Given this, our model assumes the vast majority of GH2 produced over the coming decades will be directed to the international market, with a focus on exports to the EU Region. Our results show that Brazil might become a large export player for the European market, reaching close to 20% market share by 2050, although it will depend on Brazil's comparative advantages over other global players such as Australia, Chile, and the USA, something that was not included in this version of the paper.

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