Real Options Valuation of a Green & Yellow Hydrogen Plant in Brazil

Abstract

The objective of this article is to propose a Real Options approach to the specific situation that will very probably develop in Brazil in the new few years with a significant green energy surplus and give to Green Hydrogen (GH_2) producers an opportunity or real option to get access to GH_2 production on a massive scale at a competitive price and steady supply. One possible outcome of such a scenario is the regulator exempting this GH_2 production of the so-called Wire Cost (TUST) as it is intended not for consumption but for renewable storage through GYH_2 production. We model the gains expected to be obtained by H_2 producers through two spark-sreads as switch options.

Keywords

Green & Yellow Hydrogen; Spark-pread; Hydrogen market; renewable energy; Switch options.

Introduction

Brazil has historically been a significant renewable energy producer, relying heavily on hydropower for its energy production. Its whole installed capacity at the start of the 2000 years was XXX TW with 92% of it based on hydropower, especially with large reservoir dams. This hydropower accounted for 82% of all power generated at that time.

But in 2000 – 2001 a severe drought brought the water level in its reservoirs to a historical minimum of YY% forcing the government system administrator to ration hydro generation and increasing drastically thermal power output to avoid a serious blackout all over the country. And yet this scenario was only avoided by little since the level of high tension transmission lines integration in the country was below the necessary and even the full use of backup thermal generation was insufficient to supply the default hydropower output. Only a high level of rainfall in 2002 restored the system to equilibrium and a decade that followed with normal levels of rainfall avoided the blackout menace to reappear.

Also during the next decade of 2001 to 2010, the government as regulator underwent a huge effort in investment in transmission lines and thermal generation backup turning the Brazilian system almost fully integrated (9X%) and with a significant thermal backup to face draughts as that one of 2001. This integration is by no means a small achievement considering the size of the country. Yet another fact also changed the characteristics of the whole country´s electrical system by the end of this period. The appearance of wind energy generation on a scale is much superior to what had been previously envisioned. This type of generation rapidly caught up to be the second source of renewable generation in installed capacity, in place of thermal from biomass (mostly from sugarcane bagasse, and therefore renewable also), and is still growing as an energy source. But this fact also brought a new dilemma for the system administrator. As wind generation is intermittent literally by nature, the need for a backup of a non-intermittent source also grew. And as solar photovoltaic (PV) sources also appeared, both as a regular generation source through PV farms connected to the grid (centralized generation) as well as commercial and residential distributed generation with net-metering, and grew in installed capacity on a scale similar to wind source, the intermittence of the whole system also grew significantly. Presently PV generation has also caught up with wind and ranks as the second in installed capacity only trailing hydro.

From 2012 to 2021, a series of draughts did influence the administration of the system bringing online more thermal power than was expected. But with the use of the backup already in place, the almost fully integrated system, and the new renewable generation capacity also at work, this situation was handled on a much better level than in 2001. At the present moment, with renewables generating significantly, and reservoirs at their highest level in a decade, Brazil's next years as energy supply look comfortably stable. Even more: as renewables must be dispatched with priority over other sources, and as their capacity growth shows no sign of easing up, there will probably be an excess of available renewable supply (counting large reservoirs of hydro as renewable) in the next foreseeable years.

On top of that, especially in regions with a significant availability of PV supply, hydrogen (H_2) production has been growing steadily as the green hydrogen (GH_2) market develops and becomes more and more profitable and attractive. In the North East part of Brazil, with significant renewables production (wind and PV), generators have the option of producing GH_2 instead of injecting it into the grid, as they do not have transmission cost in doing so. One possible development of the whole situation described previously is that in the next few years, it is possible to forecast that the price of free market energy in the country will drop significantly (USD?) given the surplus of supply, specifically of renewable (counting hydro) energy. As this surplus will be available countrywide in its integrated grid, it can turn into a possible base for H_2 production at a relatively low energy cost. As this can be a Yellow H_2 (YH_2) production but depending on the mix of sources composing the grid supply, a significant part of this production can come from renewables and therefore a GH_2 production in part. The advantage of such a scheme will be that H_2 production will no longer need to be close or together with the renewable source, but at any point in the grid of the country. So depending on the availability of renewable energy in the mix of the grid at a given time and location, the production of H_2 can be a mix of Green and Yellow H_2 or a GYH_2, with a defined percentile of renewables that will determine the overvalue of that specific H_2.

The objective of this article is to propose a Real Options approach to that specific situation that will very probably develop in Brazil in the new few years and give to GH_2 producers an opportunity or real option to get access to GH_2 production on a massive scale at a competitive price and steady supply. One possible outcome of such a scenario is the regulator exempting this GH_2 production of the so-called Wire Cost (TUST) as it is intended not for consumption but for renewable storage through GYH_2 production.

Hydrogen Markets

The potential insertion of hydrogen (H_2) as one of the main energy resources in the long term, replacing oil and natural gas, can be an alternative to promote the energy transition process in the Brazilian electricity sector and the world, despite the related technological challenges its production, transport, and storage.

H_2 can be used as a low- or zero-carbon energy source in sectors with difficult electrification or even as a vector for seasonal storage associated with renewable energy generation, which peaks in summer, while demand peaks in winter [1]. From the production point of view, H_2 can be classified according to the main raw material used, the process employed or the occurrence of carbon dioxide (CO_2) emissions.

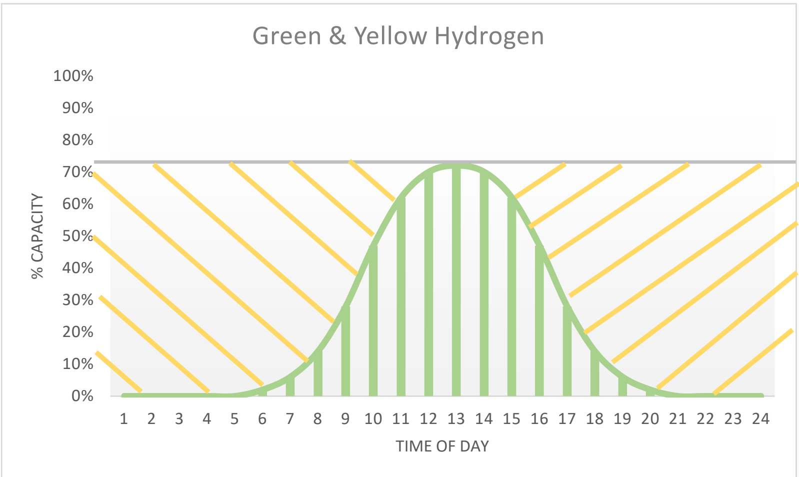
Steam Methane Reforming (SMR) accounts for approximately three-quarters of all H_2 production globally [2]. In SMR, heat, and pressure are used to convert the methane in natural gas into H_2 and CO_2. The hydrogen produced in this way is called gray, while that produced from coal gasification is called brown [1].

The blue hydrogen production process, in turn, is similar to that of gray hydrogen, since both are produced from natural gas, mostly by SMR and with CO_2 as a by-product [23]. However, blue hydrogen differs from gray because, with it, part of the CO_2 released by the SMR process is captured [2].

Hydrogen can also be generated by the electrolysis of water. When this electricity is produced by a clean and renewable source, such as hydroelectric, wind, or solar, hydrogen is called green [3].

Real Options on Renewable Applications

Valuation RO Model



$$\pi = green\ hydrogen\ option + yellow\ hydrogen\ option$$

$$\pi = Max[(p_h - p_{se}).q_{gh}, 0] + Max[(p_h - p_{ge} - tar).q_{yh}, 0]$$

The option value of the model will come from the operation of two spark-spread switch options where the producer of H_2 from direct energy from the grid can operate up to two H_2 markets dependending on several varaibles which will be modeled by adequate stochastick processes, fiting its expected behaviors. These are:

Ph – market price of H_2

p_{se} – cost of energy considering Wire Cost incentive for renewable production

p_{ge} - cost of energy considering Wire Cost incentive for partial renewable production

q_{gh} – quantity of GH_2 produced

q_{yh} – quantity of YH_2 produced

Results

Conclusions

References

[1] T. Capurso, M. Stefanizzi, M. Torresi and S. M. Camporeale, “Perspective of the role of hydrogen in the 21st century energy transition,” *Energy Conversion and Management*, vol. 251, pp. 114898, 2022.

[2] R. W. Howarth and M. Z. Jacobson, “How green is blue hydrogen?,” *Energy Science & Engineering*, vol. 9, no. 10, pp. 1676-1687, 2021.

[3] A. M. Oliveira, R. R. Beswick and Y. Yan, “A green hydrogen economy for a renewable energy society,” *Current Opinion in Chemical Engineering*, vol. 33, pp. 100701, 2021.