Large Scale Green Hydrogen Production to Help Decarbonizing the Aluminium Sector

Roland Héquet
Vice President Hydrogen Strategy & Origination
John Cockerill, Seraing, Belgium
Corresponding author: roland.hequet@johncockerill.com

Abstract

The production of alumina and aluminium are energy intensive processes and as a result, the aluminium sector is one of the largest industrial energy consumer and CO_2 emitter.

In particular, conventional alumina refining combusts natural gas to achieve the high temperatures necessary in the calcination process. The use of green hydrogen instead of natural gas is seen as one of the ways to help in reducing the sector's emission intensity. The proposed paper is to present how large-scale production of price competitive green hydrogen is possible and how it could contribute to the aluminium sector decarbonisation.

Keywords: John Cockerill, Green hydrogen, CO_2 emissions, Decarbonisation, Alkaline electrolysis.

1. Introduction

The cycle of aluminum is one of the most atypical of all metals. One of the particularities is the huge energy amount required in its production processes from mining and extraction to final products. However, it presents the huge advantage of being recycled quite easily, requiring much less energy than its primary production.

The path between the raw bauxite and the aluminum we know today is long. Aluminum is abundant in the Earth's crust; however, it cannot be found in a natural state, thus explaining its late discovery by scientists. In the environment, the principal source of aluminum is in bauxite, a sedimentary mineral composed in part of aluminum atoms.

The first step in aluminum production consists therefore in dissolving the bauxite to extract an intermediary product: alumina. These first operations are generally undertaken close to extraction sites. Alumina is then transformed onsite or shipped as raw material to aluminum smelting factories for the remaining treatments.

It is during this process that most of the CO_2 emissions are made, mainly due to the massive amount of heat which is required. On a unit basis, it is recorded that a tonne of aluminum requires roughly 75 GJ of energy. This includes fuels & electricity for bauxite mining, alumina refining and aluminum smelting. Primary production (aluminium smelting) stage is the most intensive, requiring 53 GJ per tonne of aluminium, whilst alumina refining uses 11 GJ/tonne of alumina i.e. 21 GJ/tonne of aluminium.

While it is true that electricity is the major energy type consumed in primary production processes (70%), the larger contributor CO_2 emission from aluminum production results from the onsite production of this electricity together with natural gas combusted to achieve the high temperatures necessary in the calcination process. On average, 68 % or 11.3 t of CO2 emissions per tonne of aluminum comes from the combustion of fossil fuels during alumina refining and for electricity generation. Other sources of emissions come from the consumption of the carbon anode in the electrolytic cell as well as process-related perfluorocarbons (PFC) emissions generated during operational disturbances in the electrolytic cell known as “anode effect”.

2. Hydrogen and Aluminum

Hydrogen is the most abundant element in the universe, yet is rarely found in its purest form, specifically on Earth. Rather, it is usually found as a combination with other atoms such as in water (H_2O), or with carbon in hydrocarbons (CH_4, C_2H_6). On a mass unit level, hydrogen contains three times more energy than petrol or any other fossil hydrocarbon. This can be understood intuitively when considering the combustion reactions. Combustion occurs when burning a combustible by making it react with oxygen. Therefore, the combustion of hydrogen transforms into water, whilst that of carbonated combustibles, the outcome is carbon dioxide, molecule deprived of chemical energy. Hydrogen is therefore a CO_2-free combustible. Of course, any process involving the generation of CO_2 or other greenhouse gases is now known as one of the major contributors of our world global warming and subsequent climate change effect.

Notwithstanding, for hydrogen to be fully decarbonized, we ought to make sure that the process in creating the hydrogen itself is CO_2-neutral. This is where the term of “green” hydrogen comes into play: hydrogen produced via the electrolysis of water powered by a renewable energy source (such as photovoltaic or wind).

This green hydrogen can be used in a multitude of ways to decarbonize the above-mentioned energy-intensive processes in the production of primary aluminum.

- First, hydrogen can replace natural gas combustion in obtaining very high temperature in the calcination process and to produce electricity / steam when transforming bauxite into alumina.
- Second, and as we have already assessed, the largest contributor in terms of CO_2 emissions in the production of aluminum is the on-site production of electricity from fossil fuels. This is especially true in Asia where over 75 % of the electricity is produced by the smelting companies themselves with fossil fuels, versus 50% approximately for Americas. While hydrogen’s first vocation is not electricity production (its production being electricity-intensive), it can serve as a complement to other renewable energy sources such as photovoltaic (PV) or wind during low production phases. Indeed, hydrogen can be stored in large quantities for an unlimited time period. Hydrogen could therefore be used as an emission-free combustible in producing electricity when sun or wind energies are insufficient to meet demand. Hydrogen can also be used in combination with renewable energy sources to smoothen out intermittencies in order to obtain a fully stable baseload.
- Third, hydrogen can also be used in the mining process of the bauxite by powering the ultra-heavy-duty vehicles. Several pilot projects are currently ongoing to assess the viability of the latter application in Australia, one of the largest alumina producers in the world.

Unfortunately, barriers and limitations exist. The levelized cost of green hydrogen compared to that of fossil alternatives in producing the gas is up to seven times higher. Only with sufficient support and policies will greener alternatives rise.

But the continuous cost decrease of renewable energy from solar and wind makes possible under favorable circumstances to have green hydrogen to be competitive with natural gas.

The cost of green hydrogen depends on the price of electricity for 70 to 80 %, the remaining mostly coming from the capex of the production units.

The prospects are huge with of course a special focus on the countries offering the world's largest bauxite mining production, like Australia, Guinea and China. These countries offer both the abundance of ore and extremely favorable green electricity prices, as low as 85 USD/MWh on average for the Chinese market. Australia's auctions for large-scale solar-PV installations are now going as low as 41 to 60 AUD/MWh.

Regarding the capex, the increase of size of the green hydrogen plants leads to a constant decrease of the unit price per installed megawatt. As an example, John Cockerill as world champion in the field with already more than 150 MW of electrolyzers sold this year, offers the key to reach a levelized cost of hydrogen (LCOH) between 1 and 1.5 € per kilogram of produced hydrogen.

Pressurized alkaline technology is particularly well suited for these very large production facilities. Indeed, it combines several major advantages:

- The ability to offer well-proven large-scale electrolyzer stacks (presently 5 MW with an aim at 20 MW).
- Electrolyzer outlet pressure of 30 bars without the need of compressors.
- Very well suited to the variations of solar and wind renewable energies with an ability to follow the gradients of the incoming electrical power.
- The lowest Capex and Opex.

The decarbonization of the aluminum industry will not happen overnight. The International Energy Agency (IEA) has notably identified several recommended actions, of which several have a direct implication for the hydrogen industry. Whether we look at the accelerations needed in the energy efficiency or the innovation and deployment of low-carbon primary technologies, hydrogen has its role to play.

John Cockerill, with its position as market leader in the large-scale green hydrogen electrolyzer is ready to accompany the decarbonization efforts needed to meet the Paris agreement CO_2-reduction levels.