MEMO

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Client **BP Kwinana**
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To [redacted]
From [redacted]

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1 Technical Memo

1.1 Introduction

The BP Kwinana Green Hydrogen facility (H2 Kwinana or H2K) is currently in development aiming to establish a 105 Megawatt (MW) renewable hydrogen facility with a daily production capacity of 48 tonnes of hydrogen. The hydrogen is produced through electrolysis using Low Pressure Proton Exchange Membrane (LP PEM) electrolysers, chosen for their high purity hydrogen output and minimal effluent generation. The electrolysis process involves six smaller electrolyser modules, each comprising stacks of cells, coolers, and separators. Ultra-pure water is fed into these modules, producing hydrogen at the cathode side and oxygen at the anode side (Figure 1). The operational electricity consumed by the LP PEM is solely sourced from renewable sources.

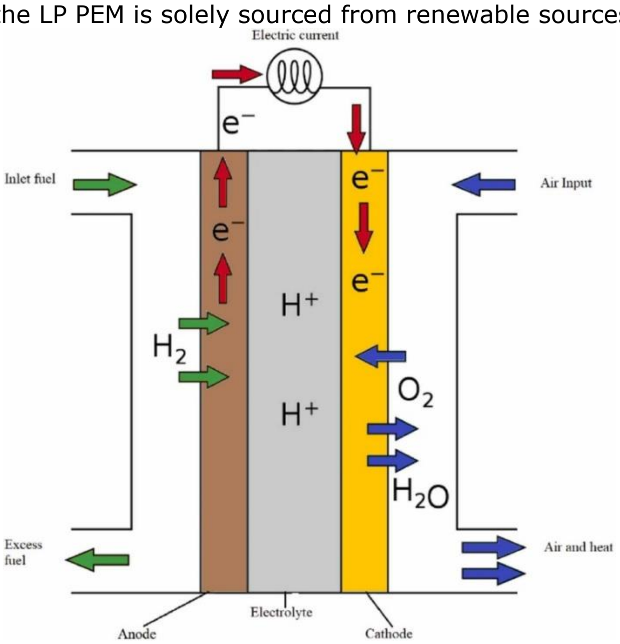

Figure 1: Schematic of Proton Exchange membrane electrolysis

Venting mechanisms are in place to ensure safety during normal and emergency operations. Oxygen gas (O_2) is continuously vented at low pressure,

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while hydrogen gas (H_2) is vented during startup, shutdown, and relief scenarios. Nitrogen is continuously introduced into the hydrogen vent headers to inhibit the entry of oxygen into the vent line. The vent streams information is outlined in Table 1.

Table 1: Vent streams

Venting stream	Venting	Venting height (m)	Venting temperature (°C)	Venting Rate (tonnes/annum)
Hydrogen	Hydrogen will be vented to the atmosphere intermittently via the hydrogen vent, during upset conditions and maintenance events such as shutdowns	30	60	11
Oxygen	Oxygen is produced during electrolysis and will be vented from a low-pressure oxygen vent on a continual basis during operation	30	40	144,540
Nitrogen	Nitrogen will be released to the atmosphere as a purging gas during commissioning and routine operations	30	-	2,772

1.2 The Fate of Vented Gasses

The three gasses which are vented; hydrogen gas (H_2), oxygen (O_2) and nitrogen (N_2) are all inert gasses that exist naturally in the atmosphere. They do not readily undergo chemical reactions to form other compounds under normal atmospheric conditions due to the valence electrons (outermost electrons of an atom) being full (Singh & Jasvinder, 2007).

The quantities of H_2 and N_2 being released are considered to be low and intermittent (Table 1). Although the amount of nitrogen gas released is not substantial, it's worth noting that nitrogen is the predominant gas in Earth's atmosphere and is exceptionally stable due to the strong triple bond between its atoms. Consequently, a considerable amount of energy is needed to break this bond and form other compounds. As a result, N_2 is generally only converted through biological processes, with some nitrogen fixed by lightning or certain industrial processes, including the combustion of fossil fuels. (Bernhard, 2010). When released into the atmosphere, H_2 has two main fates: around 70 %–80 % is estimated to be removed by soils via diffusion and bacterial uptake, and the remaining 20 %–30 % is oxidized by reacting with the naturally occurring hydroxyl radical (OH), yielding an atmospheric lifetime of around a few years (Ocko, 2022). This reaction generally occurs in the upper atmosphere and whilst it can lead to the creation of ozone (O_3) this process is not expected to occur at ground level. For these reasons, it is not anticipated that emissions of H_2 and N_2 will significantly affect air quality.

The primary byproduct of electrolysis is O_2, which is released in significant quantities (Table 1). While oxygen gas alone poses no air quality concerns, it can potentially contribute to the formation of O_3. It is however noted that this process generally occurs in the upper atmosphere (stratosphere) and is unlikely to form in the lower atmosphere or near the ground level (troposphere). Unlike stratospheric ozone, which occurs through the reaction between oxygen gas and ultraviolet (UV) radiation within a wavelength of 180-240 nanometres (nm) (wavelengths that occur more frequently in the upper atmosphere), tropospheric ozone forms through the interaction of air containing volatile and semi volatile organic compounds and nitrogen oxides under UV radiation within a wavelength of 315-400nm (Sher, 1998). Therefore, harmful pollutants including O_3 are unlikely to be formed and impact at surrounding sensitive receptor locations during venting of hydrogen, oxygen and nitrogen during electrolysis at H2K.

When several stacks are located in close proximity to each other, the resulting plume rise is different from that of a single stack. Plumes coming from the various stacks generally merge during the rise stage thus generally causing enhanced rise due to reduced ambient air entrainment and increased buoyancy (Anfossi et al, 2003). Conversely plumes with densities higher than air (Table 2) can in theory reduce the plume rise of other combustion sources and potentially increase ground level pollutant concentrations, however given the vents are located over 500m from the emissions of the nearest combustion sources, plume merging with these sources is not expected to occur and the plume rise from the combustion sources is not expected to be impacted.

Table 2: Density of the gasses associated with the venting operations

Gas	Density (kg/m^3) at 273.15 K and 1013.25 atm
Air	1.293
Hydrogen	0.084
Oxygen	1.429
Nitrogen	1.251

2 Limitations

Ramboll prepared this report in accordance with the scope of work as outlined in our proposal to BP dated 8th of May 2024 and in accordance with our understanding and interpretation of current regulatory standards.

The conclusions presented in this report represent Ramboll's professional judgement based on information made available during the course of this assignment and are true and correct to the best of Ramboll's knowledge as at the date of the assessment.

Ramboll did not independently verify all of the written or oral information provided during the course of this investigation. While Ramboll has no reason to doubt the accuracy of the information provided to it, the report is complete and accurate only to the extent that the information provided to Ramboll was itself complete and accurate.

This report does not purport to give legal advice. This advice can only be given by qualified legal advisors.

This report has been prepared for BP and may not be relied upon by any other person or entity without Ramboll's express written permission.

3 References

Anfossi, D. et al. (2003) Plume Rise. Chapter 6 of Air Quality Modeling - Theories, Methodologies, Computational Techniques, and Available Databases and Software. Vol. I - Fundamentals (P. Zannetti, Editor).

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