Engreen Environmental Consultants Ltd.

Report Title:	**Site Information**
Client:	**Geopura Ltd**
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1 Introduction

1.1 General

1.1.1 Summary

This document provides information in support of the Environmental Permit variation application for the Geopura Water Electrolysis Installation at High Marnham.

1.1.2 Installation Information

The following details are provided for the applicant.

Company Name	Geopura
Company Registration number	11855286
Site Name	High Marnham Hydrogen
Site Address	High Marnham Power Station
Grid Reference (centre of site)	SK 80923 70852
Permit Reference	
Schedule 1 Activities	S 4.2 Part A(1) (a) (i)

1.2 Permitting Requirements

1.2.1 General

The facility is required to apply for an Environmental Permit (EP) in order to comply with the Environmental Permitting (England and Wales) Regulations SI 2010/675, as variously amended.

1.2.2 Nature of Application

This is an application for a new Chemicals Installation permit.

1.3 Sector Guidance Documents

- Environment Agency Sector Guidance, “” (The Inorganic Chemicals Sector (EPR 4.03)), March 2009;
- Environment Agency guidance, “How to comply with your Environmental Permit”, (EPR 1.00), version 5, August 2012.

1.3.1 Report Format

This variation application document is structured as follows:

- Introduction;
- Process Description
- Mass Balance;
- Emissions and Wastes Description;
- Monitoring;
- Energy
- Local Amenity Control
- Conclusions.

The following additional reports have been submitted in support of this Permit Variation Application –

- P207-R02-F2 ERA – Environmental Risks and Impacts Review
- P207-R03-F2 SCR – Baseline SCR
- P207-R04-F2 BAT Review
- P207-R05-F2 EMS – Summary of EMS to be used
- P207-R06-F2 Drawings
- P207-R07-F2 – Non Technical Summary
- Application Forms and appended documents.

2 Electrolysis Process Description

2.1 Outline Description

2.1.1 General

The process is the electrolysis of water to create hydrogen gas product and oxygen gas by-product. The desired product is the hydrogen and the oxygen by-product is allowed to disperse harmlessly into the atmosphere.

2.1.2 Chemistry

The process chemistry is the simple electrolysis reaction:

$2H_2O \rightarrow 2H_2 + O_2$.

The electrolysis requires a degree of ionisation of the process water to provide the conductivity necessary for an efficient reaction. In this instance the conductivity is provided by the addition of potassium hydroxide to the electrolysis vessel. The potassium hydroxide is present simply to provide ions in the solution and so provide efficient conductivity; it does not participate in the electrolysis reaction.

2.1.3 Process Steps

The process steps involved are:

- Water purification
- Water softening
- Electrolysis
- Hydrogen export

2.1.4 Location and Layout

The installation is located on a small area of a disused power station principally on an area previously occupied by one of station’s cooling towers. The installation equipment requires very little space and will occupy approximately the same volume as 8 isotainers.

2.2 Process Details

The sections below set out the detailed descriptions of the process steps involved in the hydrogen production. Equipment details are set out in the subsequent sections.

2.2.1 Water purification

Dissolved chemicals, naturally present in all water supplies, can create unwanted side reactions during the electrolysis. The products of these reactions may inhibit continued electrolysis and/or cause corrosion and damage to the electrolysis equipment. To prevent these unwanted side reactions and damage to the processing equipment it is necessary to purify the water used in the process.

To purify to the molecular level in this way the most appropriate technique is reverse osmosis and the technique has been applied at this installation. The process water is pumped at high pressure though an array of RO tubes containing semi-permeable membranes. The applied pressure forces the water molecules through the membrane against the osmotic pressure. The cleaned water is collected for use in the process.

At intervals, and triggered by increased pressure drop across the membranes, a backwash cycle is automatically initiated to clean the membranes of accumulated material. The water flow is stopped and a reverse pressure applied from the clean side. This flushes through accumulated material which collects as “RO Concentrate” which can be disposed of as effluent.

2.2.2 Water Softening

Although the reverse osmosis is expected to produce very clean water an additional softening step has been added as extra security. The water softening will remove any residual “hard” cations such as calcium or magnesium. Hard cations are known to generate scale deposits which can interrupt flow in pipes, blind membranes and prevent valves fully seating. To minimise the possibility of such problems the cleaned water flows through a cartridge water softener in which the water passes through a bed of sodium chloride. The hard cations preferentially swap with the sodium cations and are trapped in the cartridge medium. The sodium ions do not precipitate or generate scale and so eliminate the potential problems of the hard cations.

After a period of time – likely to be many months and possibly even several years – the cartridges become depleted in sodium and loaded with hard cations. At that point the old cartridge is removed and a new one installed. The old cartridge is returned to the suppliers to be regenerated.

2.2.3 Electrolysis

Electrolysis is carried out in identical electrolysis cells, each containing a conducting solution and anode and cathodes connected to the electrical supply. Using a base as the conducting solution not only ensures good electrical performance but it also uses the hydroxyl ion which is already present in water, so minimising the potential for cross- and side-reactions.

The cell is filled with the potassium hydroxide conducting solution and the electrical supply to the electrodes is switched on. The electrical current dissociates the water into hydrogen and oxygen with hydroxyl as an intermediate:

Cathode (reduction): $2\ H_2O(l) + 2e^- \rightarrow H_2(g) + 2\ OH^-(aq)$

Anode (oxidation): $2\ OH^-(aq) \rightarrow 1/2\ O_2(g) + H_2O(l) + 2\ e^-$

Collection ducts above the electrodes collect the evolved gases.

The hydrogen flows to the compressor unit to be compressed and subsequently pumped into the tanker for despatch off-site.

2.2.4 Hydrogen Export

The collected hydrogen is compressed and pumped into industry standard arrays of hydrogen cylinders fitted to trailers. Once the arrays are full the trailer is driven from the site and replaced with an empty array.

2.3 Equipment Details

2.3.1 RO Unit

The reverse osmosis is a standard packaged unit where the water is pumped through a tube array into a collection pipe for onward use. The packaged unit is fitted with condition monitoring to ensure flows are within equipment parameters and that there is not excessive back-pressure. The pressure monitor acts to activate the reverse flow backwash to clean the membranes. Reverse flow backwash effluent collects in an integrated vessel and is discharged to effluent.

2.3.2 Ion Exchange.

A simple cartridge ion exchange unit will be installed. In these units the pumped water flows through a cartridge softener and exits to the next stage of the process. Site will carry a spare cartridge to allow for exchange without interrupting the process.

2.3.3 Electrolyser

Sixteen identical electrolysers will be installed in parallel to give the required production throughput together with turndown capability. Each electrolyser will be a standard packaged unit such as the Green Hydrogen Systems A90. With packaged units the operator simply has to supply water and electrical supplies together with pipe/ducts to take the hydrogen product an oxygen by-product. The packaged unit provides the chemical reaction tanks and the gas collection systems.

Fill points are provided to allow the potassium hydroxide to be loaded into the unit. This will either be pumped directly from a road tanker or manually pumped from IBCs.

Approximately biennially the 1000 kg potassium hydroxide charge in each cell is drained from the vessels and sent for recovery.

2.3.4 Hydrogen compressor

Hydrogen compression is via standard hydraulically driven or rotary compression units. Both options will involve closed charges of hydraulic/lubricating oil but there are no releases of either in normal operation.

On an approximately annual basis the lubricant/hydraulic oil is removed and sent for regeneration by the supplier.

2.4 Releases

2.4.1 To Air

By-product oxygen from each electrolysis cell dissipates to atmosphere via diffuser vents.

2.4.2 To Water

The electrolysis cells and associated equipment are being installed on the site of one of the old power station cooling towers. Infrastructure was constructed for the whole power station which transported collected rainwater to discharge via an engineered channel into the River Trent. This engineered channel and discharge still in existence and operational.

The cooling towers and the RO units have essentially the same discharge characteristics in that both discharges are mains water that has been slightly increased in dissolved ions – in the case of the cooling towers this is via evaporation and in the case of the RO unit it is by reverse osmosis. As such use is being made of existing site infrastructure with respect to water discharges. The RO discharge will be introduced to the overall area run-off system downstream of the rainwater hydrobrake.

2.4.3 Rainwater

Site run-off – clean rainwater – will be discharged to river via the existing overall area run-off system. An attenuation pond and hydrobrake will maintain acceptable flowrates.

2.5 Monitoring

2.5.1 Process

The electrolysis system comes as a packaged unit with integrated control panel and condition monitoring to assure optimal performance.

The RO unit has integral pressure monitoring to ensure backwashing is carried out efficiently to maintain filtration performance.

2.5.2 Releases

There is no requirement for monitoring of releases to air.

Releases to water from the RO unit will be sampled approximately monthly and analysed to confirm conformance to predicted release rates and concentrations.

3 Overall Data

3.1 Energy and Mass Balances

3.1.1 Electrolysis Main Balance

Inputs		**Step**		**Emissions**
Water 1800 kg/hr	→	**RO/Soften**	→	RO Reject 360 kg/hr
		1440 kg/hr clean water		
		↓		
Electricity 13.8 MW	→	**Electrolysis**	→	Oxygen 1280 kg/hr
		320 kg/hr hydrogen		
		↓		
Electricity 0.65 MW	→	**Compression/Store**		
		320 kg/hr hydrogen		
		↓		
		Tanker Module		

3.1.2 Electrolysis Minor Balance

In addition to the main balance above there will be a number of very minor emissions which will generally be associated with maintenance activities:

Material Released	**Reason**	**Estimated kg/yr**
Nitrogen to atmosphere	Purge system to make safe flammable atmosphere prior to maintenance or engineering work	<10
Hydrogen to atmosphere	Vent losses around seals and with oxygen from electrolyser	10-100 kg/yr
Hydrogen to atmosphere	Releases during electrolyser maintenance to purge system.	5-70 kg/yr
Hydrogen to atmosphere	Releases during compressor maintenance to purge system.	2-30 kg/yr

3.2 Raw Materials and Wastes

3.2.1 Raw Materials

Material	Use	Environmental	Quantity
Potassium hydroxide	Reaction promoter	Damaging to aquatic and plant life, corrosive.	None stored on site.
Lubricant/Hydraulic Oil	Compressor	Damaging to aquatic life, persistent in ground.	None stored on site. These are readily available materials that will be delivered on an "as-needed" basis.
Ion exchange cartridge	Ion exchange regeneration	None	N/A
Nitrogen	Purging lines prior to maintenance	None – inert gas used in small quantities.	N/A

3.2.2 Wastes for Recovery

The contents of the electrolysis bath are checked regularly to ensure that the optimum conductivity is maintained with potassium hydroxide being added as and when necessary. On an occasional basis, for which the preliminary estimate as once every 18-24 months, – the contents of the bath are collected and sent for regeneration.

Hydraulic oil will be sent for recovery with initial estimates of 1000 kg/yr.

3.2.3 Wastes for Disposal

Other than "general waste" such as from operator amenity bins there are no wastes sent for disposal.

3.3 Emissions and Control

3.3.1 Sewer

There is no process release to sewer. As described above RO concentrate will be discharged via the existing discharge pipes to river.

3.3.2 Land/Waste

No direct emissions to land.

3.4 GWP

3.4.1 Direct

Hydrogen releases are estimated at up to 100 kg/yr.

Recent analysis (news: UK government study estimates global warming potential of hydrogen (dieselnet.com)) suggests hydrogen has a GWP factor of 11 compared to CO_2. Thus the GWP for the hydrogen released is 11*100/1000 = 1.1 tonnes/yr CO_2 equivalent.

3.4.2 Indirect

Initially all electricity used at the installation will come from the grid. Over time this will be replaced by renewables generated at sister company facilities located adjacent to the electrolysis site. The calculations below are based on 100% grid electricity and so represent the maximum GWP expectations of the installation.

Electrical consumption is 14.4 MW. Over 8300 operating hours this is equivalent to 119520 MWh used.

UK GHG data for 2022 (ghg-conversion-factors-2022-condensed-set) give a CO2 equivalence factor of 0.194 kg/kWh. Thus, the GWP for the grid electricity consumed is 119520*0.194 = 23187 tonnes/yr CO_2 equivalent.

3.4.3 Displacement

The hydrogen produced will ultimately displace natural has in the fuel cycle. The ratio of heat capacities (120:50) shows that the 170 tonne per annum hydrogen will displace 6374.4tonne natural gas. This will save a release to atmosphere of 408*44/16 = 17530 tonne CO_2.

3.4.4 Total

- Maximum GWP will be 23190 tonnes/yr CO_2 equivalent if none of the produced hydrogen displaced fossil fuels.
- Initial GWP will be 23190 – 17530 = 5660 tonnes/yr CO_2 equivalent.
- With fully green electricity the GWP will be -17530 tonnes/yr CO_2 equivalent.

4 Amenity Risk

4.1 Water Impacts

An assessment of water impacts is included in report P207-R02.

4.2 Odour

There are no odour producing chemicals or processes at the installation so no need for an odour management plan.

4.3 Noise

Noise is anticipated to be 78dB at 1m from the equipment. Given the distance to receptors (500m+) and the presence of noise path disruptors in the form of buildings, walls etc there is no expectation of significant noise impacts beyond the installation.

5 Management

5.1 EMS

The installation will operate to an EMS generally in line with the principles of ISO 14001. The outline of the EMS is set out in report P207-R05.

5.2 BAT

A BAT review is in document P207-R04

5.3 Monitoring

Monthly effluent samples.

Indicative noise boundary assessments by operators.