PEMBROKE GREEN HYDROGEN PROJECT: A PEMBROKE NET ZERO PROJECT: PERMIT VARIATION

Supporting Information

JFR2794
4
1
02 July 2025

Document status

Version	Revision	Authored by	Reviewed by	Approved by	Review date
1	0	Joanna Bruce	N/A	N/A	12 February 2024
1	1	Joanna Bruce	Jennifer Stringer	N/A	13 May 2024
2	0	Joanna Bruce	RWE Generation UK Plc	N/A	14 June 2024
2	1	Joanna Bruce	Jennifer Stringer	N/A	23 July 2024
3	0	Joanna Bruce	RWE Generation UK plc	N/A	29 July 2024
3	1	Joanna Bruce	Jennifer Stringer	NA	06 September 2024
4	0	Joanna Bruce	RWE Generation UK plc	Jennifer Stringer	03 October 2024
4	1	Roger Newman	RWE Generation UK plc	Jennifer Stringer	02 July 2025

Approval for issue

Jennifer Stringer	Technical Director	2 July 2025

File Name

250702 R JFR2794 JB Pembroke Green Hydrogen Permit V4 R1.docx

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NON-TECHNICAL SUMMARY

This application is to vary environmental permit (EPR/DP3333TA) at Pembroke Power Station to include the development of a green hydrogen production facility (GHPF) at Pembroke Power Station, West Pennar, Pembroke, SA71 5SS.

The site will comprise a hydrogen production facility with electrolysers that generate hydrogen from electrical power by splitting water, hydrogen treatment equipment, hydrogen offtake pipeline, cooling equipment and HV transformer.

The electrolysers will consume circa 110-120 MW of electricity to produce around 2 tonnes per hour (t/hr) hydrogen for third party uses unrelated to Pembroke Power Station. Including the balance of plant, the total energy consumption for the facility will be up to 143 MW.

The electrolysis plant will be powered with low carbon electricity supplied primarily via grid connected renewables and will create green hydrogen for use in industrial processes. Water for the electrolysis plant will come from existing power station supplies.

A decision on which technology will be used at the GHPF has not yet been made but the two types under consideration are Proton Exchange Membrane (PEM) Electrolysis and Alkaline Electrolysis. The environmental impacts of the two potential technologies are expected to be similar in nature in terms of the footprint, scale and input requirements.

Emissions associated with the GHPF comprise oxygen byproduct, emissions from the flare which is periodically used to combust hydrogen at start-up, shut-down and during abnormal/emergency conditions, and periodic hydrogen venting under emergency conditions.

There will be no continuous process water discharges from the GHPF. Process waters will generally be reused. For AEL and PEM technology the ion exchange will be replaced and sent for regeneration off site to avoid generating wastewaters.

RWE have an existing environmental management system (EMS) covering the activities on site including the operation of proposed Green Hydrogen Production Facility. The EMS will be reviewed to ensure it covers the new activities subject to this variation.

The GHPF will be designed to comply with relevant Best Available Techniques (BAT) requirements as specified within the Environment Agency’s Review of Emerging Techniques for Hydrogen Production from Electrolysis of Water.

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1 INTRODUCTION

1.1 Background

1.1.1 RWE Generation UK plc is currently permitted (EPR/DP3333TA) for the operation of a 4.2 GW thermal input combined-cycle gas fired power station at Pembroke Power Station, West Pennar, Pembroke, SA71 5SS.

1.1.2 This variation seeks to include the operation of a green hydrogen production facility (GHPF) within the permit. The GHPF will be located on land to the west of the existing power station and will therefore extend the existing permit boundary. The GHPF will comprise a main electrolyser area, a hydrogen pipeline, an electrical connection into the National Grid substation and connections into the existing power station demineralised water supply and waste discharge pipework.

1.1.3 The electrolysers will consume circa 110-120 MW of electricity to produce around 2 tonnes per hour (t/hr) hydrogen for third party uses unrelated to Pembroke Power Station. Including the balance of plant, the total energy consumption for the facility will be up to143MW.

1.1.4 The GHPF will be powered with low carbon electricity supplied primarily via grid connected renewables and will create green hydrogen for use in industrial processes. Water for the GHPF will come from existing Power Station supplies.

1.1.5 There are two potential electrolyser technology types under consideration namely Alkaline Electrolysis (AEL) and Proton Exchange Membrane (PEM) electrolysis. The environmental impacts of the two potential technologies are expected to be broadly similar in nature in terms of the footprint, scale and input requirements, and are outlined in Section 3.3. A decision on the technology will be confirmed and the application will be updated accordingly.

1.2 Site Location

1.2.1 The GHPF will be located to the west of Pembroke Power Station and will occupy an area of circa 4ha. The main electrolyser area currently comprises of grass, with trees and other vegetation around the perimeter and in the southern section. There is a small third-party natural gas Above Ground Installation (AGI) in the north-west corner which will be excluded from the extension to the permit boundary.

1.2.2 Access to the main electrolyser area is from the main road network via the B4320 Pembroke to Angle Road to the junction at grid ref. SM 926 000, then via the road running north towards Pwllcrochan to the junction with the Pembroke Power Station access road at grid ref. SM 923 023.

1.2.3 The watercourses in the surrounding vicinity are Pembroke River 1.3 km to the east and Milford Haven Waterway approximately 650 m to the north of the GHPF.

1.2.4 The nearest European designated site is Pembrokeshire Marine/Sir Benfro Forol SAC which is immediately adjacent to the existing power station permit boundary. The nearest SSSI is Milford Haven SSSI which is also immediately adjacent to the existing power station permit boundary.

1.2.5 A site location plan showing the proposed permit boundary is provided as Drawing 2.

1.3 Operator Details

1.3.1 The Operator of the proposed facility will be RWE Generation UK plc (RWE). This will not change as a result of the variation.

1.4 Regulated Activity

1.4.1 The variation is to include the production of hydrogen which is a Schedule 1 activity under Section 4.2 Inorganic Chemicals Part A(1)(a) Producing inorganic chemicals. There is no lower threshold below which a permit is not required.

1.4.2 Directly associated activities to the hydrogen production activity include:

- Water treatment (polishing);
- Transfer and venting of oxygen;
- Buffer storage of hydrogen;
- Flaring of hydrogen; and
- Back-up generator.

1.4.3 There will also be storage of raw materials and small quantities of residues and releases which is summarised in Section 2.4 and Section 2.5.

1.5 Structure of Permit Application

1.5.1 This section provides an overview of the proposals subject to this application. This is supplemented by further details in Sections 2 – 4 as follows:

- Section 2 summarises the management systems in place;
- Section 3 provides a description of the changes to the permitted activities on site;
- Section 4 addresses the environmental risk and effects; and
- Section 5 addresses the Best Available Techniques.

1.5.2 Supporting documents, assessments and application forms are provided within the appendices list as set out in the contents page.

2 MANAGEMENT OF ACTIVITIES

2.1 Environmental Management System Summary

2.1.1 RWE have an existing environmental management system (EMS) covering the activities on site including the operation of the proposed Green Hydrogen Production Facility. The EMS will be reviewed to ensure it covers the new activities subject to this variation.

2.1.2 The EMS details the procedures for environmental management on site to minimise the environmental risk from the activities covered by the permit, albeit the environmental risk of this facility is considered low.

2.1.3 All staff and external contractors of the proposed green hydrogen facility shall be given information on the requirements of the EMS as part of the induction training.

2.1.4 A copy of the EMS shall be kept at the site for use by staff when required.

2.1.2 Site and Equipment Maintenance

2.1.1 Management systems will be put in place to ensure that the GHPF is operated as designed. These systems will not only cover normal running but will also address abnormal operation and start-up and shutdown of the facility.

2.1.2 Planned maintenance routines of the proposed facility will be established to ensure all key plant components which have the potential to affect the environmental performance of the facility remain in good working order.

2.1.3 Maintenance routines will draw on manufacturer's recommendations, modified as appropriate by operational experience during the lifetime of the facility. The operator will undertake long term maintenance and ensure that all plant and equipment is maintained in line with industry standards. Routine maintenance will be undertaken by RWE engineers, and service contract with the manufacturer is expected to be in place.

2.1.3 Staff Competence and Training

2.1.1 Staff operating the plant or providing onsite maintenance will be sufficiently trained to ensure that they are technically competent to undertake their role. The RWE staff required to interact with the plant, specifically in an emergency situation, will also be sufficiently trained to ensure they are technically competent. RWE technical specialists will be available at all times to advise as required.

2.1.2 All staff and contractors will receive training on the EMS requirements as part of their induction; this will include environmental awareness including on the terms of the environmental permit.

2.1.3 Copies of relevant plans, procedures and the environmental permit shall be kept at the site for reference.

2.1.4 Job specifications are defined within the EMS and include details on relevant qualifications and training (including where relevant, on the job training) required for that role. As a minimum, records will include details relating to the date, type of training and training provider. Records shall be available for inspection as required.

2.1.5 Procedures will also be in place to ensure that contractors undertaking work on the plant are qualified for the task they are undertaking and that they are made aware of relevant requirements of the EMS and environmental permit requirements relevant to their work. This will include all maintenance staff carrying out routine maintenance of the site in the event that any third-party maintenance is required.

2.1.4 Records

2.1.1 The operator shall maintain records of any incident, accident, emergency or non-compliances shall be kept. All monitoring (where required by the permit) including samples and analysis results shall be recorded.

2.1.2 A copy of all documents will be held in RWE’s office and made available upon request. All records shall be kept for at least six years.

2.1.1 Accident Prevention and Management Plan

2.1.1 RWE’s existing EMS contains an accident management plan (AMP).

2.1.2 The plan identifies potential incidents that could have an environmental impact, the cause and consequences; measures taken to avoid the accident happening and actions to minimise the impact on the environment from the accident.

2.1.3 Emergency response facilities will be made available on the proposed site to deal with any such incidents should they occur.

2.1.4 In the event of an accident on site, RWE will undertake investigations in order to resolve the issue and/or report the accident to emergency services and NRW, as required.

2.1.5 After the immediate actions have been undertaken to resolve the accident a non-conformance report shall be completed along with a health, safety and environment report. This shall be reviewed by RWE’s health safety and environment committee, and safety measures will be implemented.

2.1.6 The AMP will be updated to cover the GHPF. The GHPF has incorporated a suitably sized underground cellular firewater storage tank to enable run-off from firefighting to be contained in the event of a fire incident. The drainage system includes penstock valves upstream of the surface water attenuation basis which can be closed in the event of a fire or spillage to prevent contamination of clean surface water in the existing attenuation pond and ensure all contamination is held within the installation boundary. Oil interceptors (class 1) are included within the surface water drainage system, and these will be regularly emptied and maintained. Further details are shown on the draft drainage plan for the GHPF (see Drawing 4).

2.1.2 Complaints Procedure

2.1.1 A complaints procedure is in place as part of the EMS.

2.1.2 A complaint report will be completed by RWE for any complaint received at the site. This will be reviewed to decide if any corrective action is required.

2.1.3 If required the operator will send a service technician to site to resolve the issue.

2.2 Site Security

2.2.1 Security fencing will be located around the perimeter of the facility and a CCTV system which will be monitored 24/7. CCTV with video analytics will be installed along perimeter fence line as well as installed in position to see entrance/exits of critical buildings.

2.3 Energy Efficiency

2.3.1 The following section provides information on energy consumption and basic energy efficiency measures for the GHPF.

2.3.2 The GHPF plant will be powered with low carbon electricity supplied primarily via grid connected renewables. Please refer to Section 3.3 for details on renewable electricity supply.

2.3.3 An uninterruptible power supply (UPS) will be provided to ensure systems such as the control system have a continuous uninterrupted power supply and are not affected by the short gap in power between a loss of mains supply and the startup of the diesel generator. The UPS also ensures sensitive systems withstand any fluctuations in the grid supply which may occur intermittently on any power grid.

2.3.4 In addition to the UPS, a 500 kW emergency diesel generator will be provided and would only provide power to safely shutdown the plant in the event of a power failure. Routinely the generator will only be run for short periods (30 to 60 minutes) on a monthly basis for testing purposes.

2.3.5 The generator is exempt from ELVs and operating requirements on the basis it operates for less than 500 hours per annum for testing purposes only.

Basic Energy Requirements

2.3.6 Table 2-1 below provides a breakdown of the energy requirements of the installation.

2.3.7 Note that a decision has not yet been made on the fuel used in the pilot flare but the two fuels under consideration are hydrogen and propane. Pilot fuel will be confirmed following further plant design.

Table 2-1: Energy Consumption by Source

Energy Source	Annual Energy Consumption	
	Delivered	Primary
Electricity (for electrolysis)	930 GWh – 1010 GWh[1]	1117 – 1024 GWh[2]
Electricity (for balance of plant)[2]	250 GWh – 340 GWh[1]	280 – 372 GWh[2]
Propane	3.75 GWh[4]	3.75 GWh
Hydrogen[5]	20.5 MWh[5]	20.5 MWh
Diesel[6]	20 MWh[6]	20 MWh

1. Delivered electricity has been calculated on the capacity of the electrolysers at 100-120MW. Balance of plant based on the difference in the total electrical consumption of 140 MW (see paragraph 1.1.3, minus that used for electrolysis).
2. A transmission and distribution loss factor of 1.1049[1] has been used for electricity from the renewable supply to convert delivered to primary energy.
3. Calculations assume 8,424 operational hours per annum.
4. Based on total propane consumption of 6m^3/hr with a gross CV of 7.21 kWh/l and 1.885 kg/m^3 density.
5. Based on a total hydrogen consumption of 0.688 m^3/hr with a gross CV of 141.7MJ/kg and 0.09 kg/m^3 density.
6. Diesel has been calculated using diesel consumption at 100% load for a similar size energy at 12 l/hr, gross CV of 10.55 KWh/l and assuming the engine is tested for 1 hour every month.

2.3.8 Relative to the nature and scale of the site the following basic energy saving measures will be incorporated into the operating procedures:

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[1] Fuel mix disclosure data table - GOV.UK (www.gov.uk)

- The site energy usage will be measured and monitored. Annual electricity usage will be recorded; and
- When selecting plant and equipment etc energy performance will form a factor in the selection process.

2.3.9 Basic energy saving techniques will be employed at the facility, these will include:

- When selecting plant and equipment etc energy performance will form a factor in the selection process;
- Use of low energy equipment where practicable such as energy efficient lighting;
- High efficiency pumps and compressors;
- Switch off policies;
- Insulation of pipework where possible; and
- Preventative maintenance schedule for relevant plant.

2.3.10 In addition to energy saving, RWE must comply with the Low Carbon Hydrogen Standard (LCHS) to sell hydrogen. Therefore, the power will be via Power Purchase Agreement (PPA) for low carbon power to remain within LCHS emissions threshold.

2.3.11 As part of the site EMS, an energy efficiency plan will be produced which will include the following:

- Energy management policy;
- Monitoring and targeting;
- Specific energy consumption;
- Operating and maintenance procedures to reduce energy consumption;
- Energy efficiency measures/techniques; and
- Review of energy / materials consumption per tonne of paper produced.

2.3.12 See Drawing 6 for Mass Balance diagram.

2.4 Raw Material Handling and Management

2.4.1 Key raw materials, expected consumption and storage arrangements are summarised in Table 2-2 below for an AEL system and Table 2-3 for a PEM system.

2.4.2 All storage is designed in accordance with CIRIA C736F[2] guidance and secondary containment.

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[2] CIRIA C736F

Table 2-2: Raw Materials for Alkaline Technology

Raw material	Description and composition of raw material	Annual Throughput	Maximum Amount (of raw materials on site at any one time)	Storage Facility
Potassium hydroxide (KOH)	25–30%w/w solution	Replaced every 5 years equates to an average of 97 m^3 per annum.	483 m^3	Stored within a tank designed to industry standard and present within the electrolyser.
Nitrogen	> 99,8% purity	3,100 Nm^3/h (intermittent use for purging and emergency only)	30,000 l	Storage tank designed to industry standard. Refilled every 2 months.
Instrument and plant air	Compressed air	1,226,400 Nm^3 (based on 8760 hours @ 140 Nm^3/h)	20 Nm^3 (10 m^3 instrument air, 10 m^3 plant air).	15 minutes storage tank for safe shut down designed to industry standard.
Demineralised water (from Power Station to supply)	Demineralised water from Power Station demineralised water supply post treatment in polishing plant	192,700m^3 (based on 8760 hours @ 22m^3/hour)	Additional storage tank on site 7,000 m^3	Storage tank designed to industry standard.
Cooling water	Towns water supply (raw industrial water)	1,489,200m^3 (based on 8760 hours @ 170 m^3/hour from: 100 m^3/h fed into the tank. 70 m^3/h fed directly to Pembroke Power Station water treatment plant.) Plus 30 m^3 stored and used to supply the main cooling circuit at higher outside temperatures, when pure air cooling is no longer sufficient.	3,200 m^3	Storage tank designed to industry standard.

Raw material	Description and composition of raw material	Annual Throughput	Maximum Amount (of raw materials on site at any one time)	Storage Facility
Hydrogen (for pilot light system for flare)[3]	Standard commercial quality	222,504 Nm^3 (based on 8760hours @ 25.4 Nm^3/hour) 6.35 Nm^3/hour per Pilot 19.05 Nm^3 / hour	0.42 tonnes	Buffer storage tank designed to industry standard.
Propane (for pilot light system for flare) [3*]	Standard commercial quality	16,381 Nm^3 (based on 8760hours @ 1.87 Nm^3/hour) 0.47 Nm^3/h per Pilot 1.40 Nm^3/h for 3 pilots	200 m^3 of gas form 0.74 m^3 of liquid form equal to 392 kg (0.392 tonnes)	Storage tank designed to industry standard
Sodium hydroxide	50% NaOH solution	Intermittent flow during regeneration	240 l	Storage tank designed to industry standard or IBC with 110% containment and bunding. Separate secondary containment to HCl solution.
Hydrochloric acid	≥ 30% < 50% HCl solution	Intermittent flow during regeneration	600 l	Storage tank designed to industry standard or IBC with 110% containment and bunding. Separate secondary containment to NaOH solution.
Compressor oil	Standard market quality	Internal compressor cycle	300 l	Up to 1 x 205 l drum.
Sodium hypochlorite (Biocide)	≥ 10% < 15% sodium hypochlorite (NaOCl) solution	Variable, as required	2 m^3	2 x IBC with 110% containment. Limited to the inventory of a closed loop cooling system.
Corrosion inhibitor	Standard market quality	Intermittent quality control flow	1 m^3	IBC container with 110% containment.
Hardness stabiliser	Standard market quality	Intermittent quality control flow	1 m^3	IBC container with 110% containment.

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[3] Note that a decision has not yet been made on the fuel used in the pilot flare but the two fuels under consideration are hydrogen and propane.

Raw material	Description and composition of raw material	Annual Throughput	Maximum Amount (of raw materials on site at any one time)	Storage Facility
Glycol	Standard market quality	Used in closed circuit cooling water (CCCW) system	No storage	No storage, present only within the CCCW system
Diesel	Standard market quality	500 kW 24/7 (emergency back-up use)	1.3 tonnes	Diesel will be stored in compliance with Control of Pollution (Oil Storage) (Wales) regulations[4]
Deoxo catalyst	Standard market quality	Replaced once per year - < 1 tonne	One refill (<1 tonne)	One refill stored in warehouse for exchange
Adsorbent	Standard market quality	Replaced once per year - < 1 tonne	One refill (<1 tonne)	One refill stored in warehouse for exchange
Transformer Oil	Standard Market Quality	Topped up as and when required	No storage – limited to the inventory of the system	No storage – limited to the inventory of the system
Ferric Chloride	Standard Market Quality	To be confirmed following further plant design.	2 tonnes	IBC container with 110% containment.
Sodium Bisulphate	Standard Market Quality	To be confirmed following further plant design.	2 tonnes	IBC container with 110% containment.
Acrylate Polymer	Standard Market Quality	To be confirmed following further plant design.	1 tonne	IBC container with 110% containment.
Nitric Acid	Standard Market Quality	To be confirmed following further plant design.	0.5 tonnes	IBC container with 110% containment.

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[4] The Water Resources (Control of Pollution) (Oil Storage) (Wales) Regulations 2016 (legislation.gov.uk)

* [4] CIRIA C736F Containment systems for the prevention of pollution

Table 2-3: Raw materials for PEM Technology

Raw material	Concentration / Purity	Annual Throughput	Maximum Amount (of raw materials on site at any one time)	Storage Facility
Nitrogen	> 99,8% purity	8,400 Nm^3/h (intermittent use for purging and emergency only)	30,000 l	Storage tank designed to industry standard
Instrument and Plant Air	Compressed air	1,226,400 Nm^3 (based on 8760 hours @ 140 Nm^3/h)	20 Nm^3 (10 m^3 instrument air, 10 m^3 plant air)	15 minutes storage tank for safe shut down designed to industry standard.
Demineralised water (from Power Station to supply post treatment in polishing plant)	Demineralised water from Power Station demineralised supply post treatment in polishing plant	183,960m^3 (based on 8760 hours @ 21m^3/hour)	Additional storage tank on Site 7,000 m^3	Storage tank
Cooling water (from Power Station demineralised supply)	Towns water supply.	1,489,200m^3 (based on 8760 hours @ 170 m^3/hour from: 100 m^3/h fed into the tank 70 m^3/h fed directly to Pembroke Power Station water treatment plant. 30 m^3 stored and used to supply the main cooling circuit at higher outside temperatures, when pure air cooling is no longer sufficient.	3,200 m^3	Storage tank designed to industry standard.

Raw material	Concentration / Purity	Annual Throughput	Maximum Amount (of raw materials on site at any one time)	Storage Facility
Resin filters	mixed bed filter bottles /cartridges	36 mixed bed filter bottles /cartridges each containing 100 litre, Total 3,600 litres	42 mixed bed filter bottles /cartridges each containing 100 litre, Total 4,200 litre	Fixed installed 6 cartridges per module, one set of 6 cartridges stored in warehouse for exchange
Hydrogen (for pilot light system for flare)[5]	Standard commercial quality	222,504 Nm^3 (based on 8760hours @ 25.4 Nm^3/hour) 6.35 Nm^3/hour per Pilot 19.05 Nm^3 / hour	0.42 tonnes	Storage from buffer tank
Propane (for pilot light system for flare)[6]	Standard commercial quality	16,381 Nm^3 (based on 8760hours @ 1.87 Nm^3/hour) 0.47 Nm$^{3/}$h per Pilot 1.40 Nm^3/h for 3 pilots	200 m^3 of gas form 0.74 m^3 of liquid form equal to 392 kg (0.392 tonnes)	Storage tank designed to industry standard
Compressor oil	Standard market quality	Internal compressor cycle	300 l	Up to 1 x 205 l drum.
Sodium hypochlorite (Biocide)	≥ 10% < 15% sodium hypochlorite (NaOCl) solution	Variable, as required.	2 m^3	2 x IBC with 110% containment. Limited to the inventory of a closed loop cooling system.
Corrosion inhibitor	Standard market quality	Intermittent quality control flow	1 m^3	IBC Container with 110% containment
Hardness stabiliser	Standard market quality	Intermittent quality control flow	1 m^3	IBC Container with 110% containment

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[5] Note that a decision has not yet been made on the fuel used in the pilot flare but the two fuels under consideration are hydrogen and propane.

Raw material	Concentration / Purity	Annual Throughput	Maximum Amount (of raw materials on site at any one time)	Storage Facility
Glycol	Standard market quality	Used in water cooling system (closed circuit loop)	No storage	No storage present only within the CCCW system.
Diesel	Standard market quality	500 kW 24/7 (emergency back-up use)	1.3 tonnes	Diesel will be stored in compliance with Control of Pollution (Oil Storage) (Wales) regulations[6]
Deoxo catalyst	Standard market quality	Replaced once per year - - <1 tonne	No storage	One refill stored in warehouse for exchange
Adsorbent	Standard market quality	Replaced once per year - - <1 tonne	No storage	One refill stored in warehouse for exchange
Transformer Oil	Standard Market Quality	Topped up as and when required	No storage – limited to the inventory of the system	No storage – limited to the inventory of the system
Ferric Chloride	Standard Market Quality	To be confirmed following further plant design.	2 tonnes	IBC container with 110% containment.
Sodium Bisulphate	Standard Market Quality	To be confirmed following further plant design.	2 tonnes	IBC container with 110% containment.
Acrylate Polymer	Standard Market Quality	To be confirmed following further plant design.	1 tonne	IBC container with 110% containment.
Nitric Acid	Standard Market Quality	To be confirmed following further plant design.	0.5 tonnes	IBC container with 110% containment.

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[6] The Water Resources (Control of Pollution) (Oil Storage) (Wales) Regulations 2016 (legislation.gov.uk)

2.4.3 Of the materials above, water used within the electrolysers to generate hydrogen is the primary raw material. Usage of raw materials will be controlled to minimise usage and avoid wastage.

2.5 Avoidance, Recovery and Disposal of Wastes

2.5.1 The GHPF will produce wastewater from the onsite water treatment process. The electrolyser recycles any wastewater from the process i.e. condensate is re-routed to a storage tank and reused in the demineralised water supply. Wastewater is also produced discontinuously from the polishing unit during regeneration, this water is also re-used within the GHPF.

2.5.2 The hybrid cooling tower system, if selected will periodically generate a purge stream. The cooling tower purge will be recycled to the inlet of the water treatment plant. The electrolysers will operate within current power station operational limits and there will be no changes to the nature of the release in the existing permit.

2.5.3 Waste generation from maintenance is infrequent. The main wastes produced are associated with periodic replacement of plant items:

AEL Technology

- Potassium Hydroxide – Not stored on site, directly removed from site after being replaced approximately every 5 years and disposed via licensed waste management contractor. Options for reuse will depend upon the quality however this is unknown at this time. An average of 97 m^3 waste produced per annum.
- Compressor Oil – Up to 1 x 205 l drum. Directly removed from site after being replaced as and when required. Options for reuse will depend upon the quality however this is unknown at this time. 300 l waste produced per annum.
- Transformer Oil – Up to 1 x 205 l drum. Limited to the inventory of the system.
- Electrolyser stacks – Replaced every 8 to 10 years and removed off site. Stacks will be refurbished rather than directly replaced and disposed to reduce waste production.
- Oxygen - Not stored on site, it will be released as produced at 13,600 - 15,200 kg/hour. Circa 130,000 tonnes per annum oxygen produced.
- Deoxo catalyst – One refill stored in warehouse for exchange. Directly removed from site after being replaced approximately once a year.
- Adsorbent - One refill stored in warehouse for exchange. Directly removed from site after being replaced approximately once a year.
- Wastewater discharge from regeneration. Every 5-6 years with the discharge tankered offsite for treatment and disposal.

PEM Technology

- Resin filters – replaced every 9 months. Will be removed on site prior to being replaced.
- Compressor Oil – Up to 1 x 205 l drum. Directly removed from site after being replaced as and when required. Options for reuse will depend upon the quality however this is unknown at this time. 300 l waste produced per annum.
- Transformer Oil – Up to 1 x 205 l drum Limited to the inventory of the system.
- Electrolyser stacks – Replaced every 8 to 10 years and removed off site. Stacks will be refurbished rather than directly replaced and disposed to reduce waste production.
- Oxygen - Not stored on site, it will be released as produced at 13,600 - 15,200 kg/hour. Circa 130,000 tonnes per annum oxygen produced.

- Deoxo catalyst – One refill stored in warehouse for exchange. Directly removed from site after being replaced approximately once a year.
- Adsorbent - One refill stored in warehouse for exchange. Directly removed from site after being replaced approximately once a year.
- Wastewater discharge from regeneration. Tankered off site for treatment and disposal.

3 OPERATIONS

3.1 Overview

3.1.1 The green hydrogen production facility (GHPF) electrolysers will have a rated capacity of 110-120 MW, comprising multiple electrolyser modules. It will be operated independently of the Power Station although will share some common utility linkages. Power to the GHPF will come from grid-connected renewables supplied from the National Grid substation located on-site.

3.1.2 The GHPF will be capable of generating circa 17,000 tonnes hydrogen per annum for third party uses unrelated to Pembroke Power Station. Including the balance of plant, the total energy consumption for the Proposed Development will be up to 143MW.

3.1.3 Most of the hydrogen produced by the electrolysis plant will be transferred to the Valero Pembroke Refinery via a 1.5 km pipeline which will run parallel to an existing natural gas pipeline, at a rate of approximately 2,000kg/hr. Note that it was agreed with NRW that the pipeline is not required to be within the permit boundary.

3.1.4 See Drawing 5 for Process Flow Diagram.

3.2 Water Treatment Plant

3.2.1 Demineralised water will be delivered by pipe from the existing power station demineralised water tank. The installed power station water treatment plant has sufficient capacity to supply the demand of the GHPF.

3.2.2 This tank has a capacity to hold 10,000 m^3 of demineralised water. The existing water treatment plant is oversized for the current power station demand and therefore has capacity to provide demineralised water to the new green hydrogen. RWE will complete some upgrade works to restore the tank to nameplate capacity.

3.2.3 The water treatment plant can produce 60 m^3/hour of demineralised water. The current power station demand is only 25 m^3/hour meaning there is spare capacity for 35 m^3/hour available.

3.2.4 The demineralised water from the existing power station supply will go through a polishing unit within the green hydrogen plant. The polishing unit will comprise mixed bed ion exchange. The polished demineralised water will be dosed with corrosion inhibitor and hardness stabiliser.

3.2.5 For both PEM and AEL technology the ion exchange resins will be replaced and removed off site for regeneration to avoid generating wastewaters.

3.2.6 Treated water is stored within a local demineralised storage tank within the green hydrogen facility. For details on how the site minimises the quantity of water used please refer to Section 5.6.

3.2.7 See Drawing 7 for Water Balance.

3.3 Electrolysis

3.3.1 A decision on which electrolyser technology will be used at Pembroke has not yet been made and the two types of electrolyser under consideration are PEM and AEL. Although the electrolyser technology remains under review the environmental performance and impacts of the two potential technologies are expected to be broadly similar.

3.3.2 The electrolysis plant will be powered with low carbon electricity supplied primarily via grid connected renewables. The power for the electrolyser plant will be supplied via a low carbon Power Purchase Agreement (PPA) with RWE sister company, RWE Supply and Trading (RWEST). This is based on the aggregation of several power generation sources from within and outside of RWE's portfolio.

3.3.3 The PPA sells the title of the power and environmental attributes to RWE and manages the flow of power to ensure that it meets the requirements of the Low Carbon Hydrogen Standard (LCHS) as will be required by the Low Carbon Hydrogen Agreement (LCHA), the contract RWE would have if successful in getting Hydrogen Business Model Hydrogen Allocation Round 2 funding.

3.3.4 There will be ongoing reporting requirements in the LCHA to show that all power used for the hydrogen production is in line with the LCHS.

Option 1 – Alkaline Electrolysis (AEL)

3.3.5 AEL uses two electrodes operating in a water and liquid electrolyte solution. If AEL electrolysis is selected potassium hydroxide solution would be the electrolyte. The electrodes are separated by a thin diaphragm which separates the product gases and leads to the transport of hydrogen ions from one electrode to the other.

3.3.6 The reactions taking place at the anode and cathode in the AEL electrolysers are:

Anode: $2OH^- \rightarrow \frac{1}{2} O_2 + H_2O + 2 e^-$

Cathode: $2H_2O + 2 e^- \rightarrow H_2 + 2OH^-$

Overall: $H_2O \rightarrow H_2 + \frac{1}{2} O_2$

3.3.7 The AEL technology is expected to include 11 modules of 10 MW and 6 modules of 20 MW.

Option 2 - Proton Exchange Membrane (PEM)

3.3.8 With PEM technology, water is split into hydrogen and oxygen using an ionically conductive solid plastic polymer. The polymer membrane allows higher current density compared with the AEL cells, enabling a more compact design.

3.3.9 In each of the PEM electrolysers, the solid ion conducting electrolyte membrane allows the H+ ion to transfer from the anode side of the membrane to the cathode site where it combines with electrons to form hydrogen.

3.3.10 The reactions taking place at the anode and cathode in the PEM electrolysers are:

Anode: $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

Cathode: $4H^+ + 4e^- \rightarrow 2H_2$

Overall: $H_2O \rightarrow H_2 + \frac{1}{2} O_2$

3.3.11 The PEM technology is expected to comprise 6 electrolysis modules with a rated capacity of 20 MW.

3.4 Cooling

3.4.1 The electrolysis process using PEM or AEL technology generates heat and therefore cooling is required. A closed loop cooling water system with a water glycol mixture will provide cooling and will itself in turn be cooled. Two cooling options are under consideration:

- Air Cooling System
- Hybrid Wet/Dry Cooling System

Option 1: Air Cooling System

3.4.2 The fin-fan air cooling system would provide 100% of the duty by dry cooling and will consist of 5 cooling units. The fin fan air coolers will be installed directly on the main cooling loop and no secondary cooling loop would be required.

Option 2: Hybrid Cooling System

3.4.3 A hybrid cooling system comprising a mix of dry air and wet evaporative cooling.

3.4.4 Cooling water to the hybrid cooling towers (24 - 30 cells) is expected to be taken from the buffer tank which is connected to the existing Welsh Water supply to the Power Station.

3.4.5 The cooling tower purge is discharged to the surge tank from where it is recycled into the inlet of water treatment plant thereby avoiding the need to discharge the purge water. It is estimated that the available water will be able to provide up to 70% of the required cooling duty, with the remaining 30% being provided by fin-fan air cooling.

3.4.6 The proposed design of the hybrid cooling system will therefore not affect the existing sea water abstraction or introduce additional thermal discharges as it does not require any interaction with the marine environment.

3.4.7 For information on the BAT for cooling please refer to Section 5.3.

3.5 Hydrogen Purification

3.5.1 Raw hydrogen gas from the electrolysers contains traces of oxygen and moisture. These trace contaminants are reduced within the hydrogen purification stage.

3.5.2 Hydrogen from the electrolysers is initially preheated within the deoxygenation (deoxo) heater using heat from electrolyser production. The heated hydrogen then enters the deoxo reactor. The deoxo reactor contains a catalyst bed to catalytically remove oxygen from the raw hydrogen stream.

3.5.3 The hydrogen is subsequently cooled to condense water. This condensate water is removed from the hydrogen gas in the hydrogen separator.

3.5.4 Further moisture removal from the hydrogen gas is provided within the adsorption dryers. The adsorption dryer will contain heated packaging. At least two adsorbers, each capable of handling the complete hydrogen flow will be provided. One dryer will be regenerated whilst the other is in operation. Regeneration of the adsorber units will utilise heated hydrogen.

3.5.5 A fine particulates filter (< 5 µm) will be installed after adsorption drying. The filter shall be installed redundantly.

3.5.6 Condensate from the gas cooling is recovered and returned for re-use.

3.6 Hydrogen Storage and Supply

3.6.1 Hydrogen gas following purification will be compressed to higher pressure for export off-site for use by end users. The compressors will be contained within the hydrogen gas compressor building located to the north of the electrolyser building.

3.6.2 There is one hydrogen storage vessel operating as a buffer tank associated with the green hydrogen plant. Note that buffer storage is not necessarily required as hydrogen will be sent directly out by pipeline to Valero Pembroke Refinery, however it has been included in the project design as it will minimise the need to flare hydrogen in the event of an issue with the off taker.

3.6.3 Hydrogen will be stored on site as follows:

Table 3-1: Hydrogen Storage and Compression

Storage	Volume (m^3)	Pressure (barg)	Mass Flow (t/hr)
Electrolyser H_2 Buffer Vessel	1.5	30	3
Industrial Offtake H2 Buffer Vessel	6	400	12

3.6.4 Hydrogen will be stored in a 1.5 m^3 electrolyser buffer vessel at a pressure of 30 barg.

3.6.5 The hydrogen produced by the electrolysis plant will be transported to Valero Refinery via a circa of 1.5 km pipeline, at a rate of approximately 2 t/hr.

3.7 Hydrogen Flare

3.7.1 Under start-up and shutdown and certain emergency conditions there may be a need to flare hydrogen. Flaring of hydrogen will be required to support events such as periodic depressurisation of hydrogen systems, to allow safe shutdown for routine and emergency situations, as well as to prevent the accumulation of hazardous atmosphere within the plant.

3.7.2 The hydrogen flare stack will be located towards the northern boundary and will be up to 500 mm in radius and 25 m in height.

3.7.3 The flare will include three pilot lights which will continuously operate and will burn either propane or hydrogen supplied from a buffer tank. Note that a decision has not yet been made on the fuel however storage supplies for both propane and hydrogen are included in Table 2-2 and Table 2-3 for information.

3.7.4 The flare will be designed following BAT guidance and will provide safe dispersion of hydrogen to the atmosphere. See Section 5.4 for further details.

3.8 Management of Oxygen Byproduct

3.8.1 Oxygen collected from the anode will be via a vent located at high level on the roof of the electrolyser building. The vent will be designed to ensure safe dispersion of oxygen.

3.8.2 There is potential for oxygen from the electrolysers to be sent to an off-taker and undergo further purification. There is sufficient land available within the revised boundary between the hydrogen storage tanks and the nitrogen/instrument air unit to facilitate this if needed.

3.8.3 In the event that an end user/outlet is identified, this would be subject to a separate application to vary the permit.

3.9 Control System

3.9.1 The GHPF will be controlled by an automatic control system. The control system will be connected to an uninterruptible power supply (UPS) ensuring that in a fault event the electrolyser plant can still be shut down safely.

3.9.2 A local control room will be located to the south of the electrolyser building however the plant will be capable of being operated remotely from the power station control room.

4 EMISSIONS AND MONITORING

4.1 Emissions to Air

4.1.1 The GHPF plant will discharge oxygen from the electrolysis process via a vent located at high level on the roof of the electrolyser building. Oxygen is not an air quality pollutant and consequently there are no AQ limits which require abatement of this release. There may be trace amounts of hydrogen in this stream, however hydrogen is not an air quality pollutant and therefore will not give rise to significant impacts.

4.1.2 Flaring of hydrogen will also be required to support events such as periodic depressurisation of hydrogen systems, to allow a safe start-up and shutdown for routine and emergency situations, as well as to prevent the accumulation of a hazardous atmosphere within the plant. The flare will include three pilot lights which will operate continuously burning either propane or hydrogen gas. The flare will be located a safe distance from the electrolyser building and hydrogen storage tanks. It is expected that the flare stack will be circa 25m in height.

4.1.3 The RWE Generation UK EMS contains a Group procedure for ensuring compliance with the F-Gas regulations GMD ENV 010, and includes a specific section for use of SF6 in switchgear including training requirements, leak checks, record keeping and SF6 recovery.

4.1.4 For a discussion on BAT in controlling emissions to air, please See Section 5.4.

4.1.5 See Section 4.6 for details on fugitive emissions.

Impacts

4.1.6 The Air Quality Standards Regulations 2010 [[i]], amended by The Environment (Miscellaneous Amendments) (EU Exit) Regulations 2020 [[ii]], sets limit values for ambient air concentrations for the main air pollutants: particulate matter (PM_{10} and $PM_{2.5}$), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ozone (O_3), carbon monoxide (CO), lead (Pb) and benzene, certain toxic heavy metals (arsenic, cadmium and nickel) and polycyclic aromatic hydrocarbons (PAHs).

Table 4-1: Summary of Relevant Air Quality Limit Values, objectives and EALs

Pollutant	Averaging Period	Objectives/ Limit Values	Not to be Exceeded More Than
Nitrogen Dioxide (NO_2)	1 hour	200 $\mu g.m^{-3}$	18 times per calendar year
	Annual	40 $\mu g.m^{-3}$	-

4.1.7 For short-term NO_2, the air quality objective is for the hourly-mean concentration not to exceed 200 $\mu g.m^{-3}$ more than 18 times per calendar year.

4.1.8 Initial information on the emissions to air from the GHPF indicate that the flare will operate during start-up and shutdown. It is estimated that there may be up to 15 start-up and shut-down events per year. The duration of flaring for each shutdown is expected to be circa 5 minutes and for each startup (assuming cold start-up) the flare will operate for 10 minutes. On this basis emissions from flaring for each event will be short-term. As the flare will not operate for more than 18 times a year, the objective is considered to be met. On this basis an assessment of emissions from the flare is not considered significant and further assessment of air quality impacts is not required. Once firm data for the selected GHPF is available this position will be reviewed to ensure it remains appropriate.

4.1.9 Oxygen will also be released to air, however as oxygen is not an air pollutant there is no requirement to assess the impact from these emissions.

4.2 Emissions to Water and Sewer

4.2.1 Discharges to water from the GHPF will comprise:

- Clean water run-off
- Discharge from the polishing unit.

4.2.2 Clean surface rainwater will discharge from the GHPF via class 1 interceptors into a series of swales and ultimately into the existing attenuation pond, as shown in Drawing 4 – Drainage Plan. This water is considered clean.

4.2.3 There will be no continuous discharge on site and process waters will generally be reused as described in Section 5.6.

4.2.4 The demineralised water from the existing power station supply will go through a polishing unit within the green hydrogen plant. The polishing unit will comprise mixed bed ion exchange.

4.2.5 There will be no continuous aqueous waste produced on site by the GHPF. For AEL technology, hydrochloric acid and sodium hydroxide will be used for ion exchange regeneration which will take place every 5 - 6 years. However, the discharge will be tankered off site for treatment and disposal to avoid the generation of wastewaters on site. Regeneration for PEM technology will similarly be taken off site to be assessed to avoid the generation of wastewaters.

4.3 Emissions to Land

4.3.1 There will be no point source emissions to land from the GHPF.

4.4 Odour

4.4.1 The GHPF has a low potential for odour generation with the main materials present and produced being water, hydrogen and oxygen. Hydrochloric acid solution (≥ 30% < 50% volume) has a pungent odour. However will be stored in low quantities and will be contained in a 600 l bunded tank. The potential for odour nuisance from use and storage of this material is considered low.

4.4.2 Diesel will be used to fuel the backup generator. It will be stored in a 1,500-liter tank in compliance with the Control of Pollution (Oil Storage) (England) regulations[7]. The generator will be tested for up to an hour once a month to ensure it functions properly and therefore usage is low. The potential for odour nuisance from use and storage of this material is considered low.

4.5 Noise

4.5.1 A Noise Impact Assessment has been completed for GHPF which concluded projected sound levels from the facility are at a low level. This is included in Appendix B.

4.5.2 The electrolysers and compressors will operate within a building which will reduce the potential for external noise nuisance. The compressors and electrolyser plant are provided with additional sound insulation to reflect the BAT for minimising sound emissions.

4.5.3 The cooling system has been assessed for noise impact and no significant impact was identified.

4.5.4 The flare will only operate during start up, shut down and any emergency shut down situations. Under normal operation of the GHPF only the pilot light would be in continuous operation, not the

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[7] The Control of Pollution (Oil Storage) (England) Regulations 2001 (legislation.gov.uk)

flare itself. Operation of the pilot light would involve low gas flows which would not be expected to result in significant sound emission.

4.6 Fugitive Emissions

4.6.1 The potential fugitive emissions from the site include are leaks of glycol, diesel, oil from the compressor, and chemicals including: sodium hydroxide, hydrochloric acid, biocide, corrosion inhibitor, and hardness stabiliser, KOH (for AEL system).

4.6.2 Procedures will be put in place, as part of the environmental management system, for the facility to minimise the risk of fugitive emissions from the site, to include:

- Spill kits will be located at strategic locations around the site and a spills procedure will be in place to ensure that any spill will be dealt with promptly.
- Regular inspections of the production areas to identify the build-up of dust and an effective housekeeping regime will be employed to minimise fugitive dust and fire hazards.
- All chemical storage tanks/containers will be appropriately bunded in accordance with CIRIA 736F to industry standard and with 110% secondary containment.

4.6.3 The hydrogen handling systems will be designed and maintained to be leak free, and will be inspected and maintained to minimise fugitive emissions throughout the life of the facility. The GHPF will meet UK Low Carbon Hydrogen Standard requirements for fugitive hydrogen emissions including the associated risk reduction plan and annual reporting requirements.

4.7 Monitoring

4.7.1 The only continuous emission to air is oxygen. Emissions will be monitored in compliance with LCHA requirements as a minimum. The LCHA reporting is required to consider all emissions from site and assign these to half hourly reporting units in order to comply for subsidy. Emissions monitoring is inclusive of hydrogen emissions which are reported under the fugitive emissions calculator. Full monitoring equipment and capabilities to be defined during the front-end engineering design (FEED).

4.7.2 The flare is only operated during abnormal/emergency conditions and therefore monitoring of emissions from the flare is not proposed. A record of the start and end of a flaring event will be made.

4.7.3 There will be no new continuous discharge that requires monitoring. Emissions to water associated with the GHPF feed water are produced in the existing Power Station demineralised water plant and will continue to be monitored in accordance with the current permit requirements.

5 BEST AVAILABLE TECHNIQUES

5.1.1 This section provides additional supporting information for the selected BAT for the key plant items as follows:

- Selection of Electrolysis Technology
- Selection of Cooling System
- Emissions to Air and Water
- Hydrogen Purification

5.1.2 This section addresses the BAT requirements as set out in the Environment Agency (EA) guidance for the production of hydrogen: emerging techniques on how to prevent or minimise the environmental impacts of hydrogen production by electrolysis of water[8].

5.1.3 Note the NRW variation charging tool makes reference to BAT Conclusion documents. Pre-Application discussions with NRW indicated that the appropriate BAT guidance for the production of hydrogen is the emerging techniques, as above.

5.2 Selection of Electrolysis Technology

5.2.1 There are a range of emerging technologies for hydrogen production by electrolysis of water with varying technology readiness levels. The following technologies have been identified by the EA[9] as emerging techniques for consideration:

- Anion Exchange Membrane (AEM)
- Membrane free electrolyser
- Direct photo electrolysis
- High pressure electrolyser
- Microbial electrolysis
- Plasma electrolysis
- Solid Oxide Electrolyser Cell (SOEC)
- Alkaline Electrolysis (AEL)
- Proton Exchange Membrane (PEM)

5.2.2 Of the above, the following electrolysis technologies are still at research and development level and have not yet proven at a pilot scale, and therefore not suitable for consideration for a commercial scale application, particularly at the scale of the GHPF:

- Anion Exchange Membrane (AEM)
- Membrane free electrolyser
- Direct photo electrolysis
- High pressure electrolyser
- Microbial electrolysis

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[8] Hydrogen production by electrolysis of water: emerging techniques - GOV.UK (www.gov.uk)

[9] https://www.gov.uk/guidance/hydrogen-production-by-electrolysis-of-water-emerging-techniques

- Plasma electrolysis

5.2.3 SOEC technology is an emerging technology that offers the potential for high electrical efficiency as it operates at elevated temperatures (500 to 1,000°C) resulting in faster reaction kinetics. However, SOEC is acknowledged by the EA within guidance as being at a low technology readiness level and has only been proven at a smaller scale. SOEC would therefore also not be suitable for GHPF and has been discounted from further consideration.

5.2.4 Based on the above, there are only two potential electrolyser technology types which have been proven at larger scale and could be employed at the GHPF, namely AEL and PEM. These two technologies are reviewed below.

Option 1: AEL Technology

5.2.5 Alkaline Water Electrolysis has been selected as a potential suitable option for Pembroke Green Hydrogen as it is a well-established technology for producing hydrogen with hundreds of operational units operating at industrial scale over 10 MWe. AEL is an operationally flexible technology as it operates at relatively low temperatures (70 - 90° C). Alkaline electrolysers avoid the use of precious metals and have a long-expected lifetime varying from 60,000 – 80,000 hours, making it a cost-effective option.

5.2.6 Whilst this is a mature technology, there are recent and ongoing developments focused on improving efficiency and supporting higher current densities as AEL technology generally operates at low current densities (0.2 – 1.0 A/cm^2). Historically AEL has not been required to respond rapidly to electrical supply variations, and improving start-up and response times is a focus area for research and development.

Option 2: PEM Technology

5.2.7 PEM is another commercially available technology being considered and is well established in conjunction with renewable power sources such as wind and solar.

5.2.8 An advantage of PEM is it operates at relatively low temperatures (50 to 80°C) resulting in a high turndown capability, rapid start-up and response to load changes. PEM electrolysers are typically installed as a single stack, or multiple stacks, to achieve higher production rates and can achieve high purity of gases.

5.2.9 Expected lifetime of PEM electrolysers vary from 50,000 – 80,000 hours, however the reliability and lifetime characteristics of large-scale stacks will be understood better once they have been in operation for a number of years.

5.2.10 PEM electrolysers can place a demand on platinum and iridium resources, and may contain PFAS if used in membranes/seals. Should a PEM system be preferred consideration of these factors will be included within the final decision.

Table 5-1: Electrolyser Key Performance Indicator (KPI) Comparison

KPI / Parameter	Units	Alkaline	PEM
Cell temperature	°C	70 – 90	50 – 80
Pressure	barg	< 30	< 30

KPI / Parameter	**Units**	**Alkaline**	**PEM**
Current density	A/cm^2	0.2 – 1.0 (present) > 2 (2050)	1 – 3.3 (present) 4 – 6 (2050)
Hydrogen purity (post drying)	%	99.9 – 99.9998	99.9 – 99.9999
Voltage	V	1.4 – 3	1.4 – 2.5
Voltage efficiency (LHV) (Note 1)	%	50 – 75	50 – 68
Stack power requirement (Note 1)	kWh/kg H_2	45 – 66	45 – 66
Lifetime	h	60 – 80k	50 – 80k
Stack size (Note 2)	MWe	1 – 20	1 – 2
Cold start	min	< 50	< 20
Minimum load	turndown %	15	5

* Information reproduced from the EA's Review of Emerging Techniques for Hydrogen Production from Electrolysis of Water[10]

5.2.11 The performance comparison in Table 5-1 suggests that PEM and AEL technologies have similar performance. Of note power consumption per kg/H_2, with both technologies are in a similar range of 45-66 kWh per kg H_2..

5.2.12 Available data[11] suggests the consumption of demineralised water by both PEM and AEL technologies are broadly similar. PEM technology is reported to consume approximately 0.02 m^3/kg H_2 (albeit noted that this was from a single reference source) whereas AEL consumes approximately 0.01-0.02 m^3/kg H_2.

5.2.13 Both PEM and AEL technologies remain under consideration for the GHPF. The environmental performance of these technologies are similar and therefore either can be considered as BAT.

5.3 Selection of Cooling System

5.3.1 RWE have undertaken a review of potential cooling options for the GHPF to inform the selection process. Various alternative technologies were considered for the cooling system. The options considered were:

- Wet cooling tower.
- Connection to existing combined cycle gas turbine.
- Connection to seawater

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[10] Review of emerging techniques for hydrogen production from electrolysis of water (publishing.service.gov.uk)

[11] JEP21WT07 A Review Of Water Use For Hydrogen Production (energy-uk.org.uk)

- Air cooling
- Hybrid wet/dry cooling system

5.3.2 A wet cooling tower has been discounted on the basis there is currently insufficient available make-up water for a wet cooling system alone to meet the cooling demand of the hydrogen production facility. It is estimated that approximately 50 m^3/hr of make-up water would be required for the wet cooling system which is greater than the available water to be used for make-up at the power station.

5.3.3 Connection to the existing combined cycle gas turbine was considered but there are a number of complexities including:

- Complexity in connecting to all five CCGT units to ensure electrolyser cooling availability at all times.
- Complexity of integrating the control systems of the GHPF with the existing power station plant control system.
- Complexity of integrating into the existing cooling water pumps due to a lack of a variable speed drive and water availability at maximum power station demand.

5.3.4 The cooling system to the power station operates under an abstraction licence which limits the volume of water that can be abstracted and the environmental permit which limits the heat load of the return water with both an absolute temperature limit and a limit on temperature increase. Operational data indicates that the current cooling system is at times already at maximum cooling capacity and therefore there is no availability for cooling the GHPF within the existing permit and abstraction licence limits. For the above reasons this option is considered not feasible.

5.3.5 The facility is located in proximity to the Milford Haven water course. The use of a separate water abstraction from the Milford Haven could be an option and would require an abstraction licence and would also introduce a further discharge with associated thermal load. Uncertainties in securing and maintaining an abstraction licence for sufficient volumes of cooling water have discounted this option

5.3.6 Both an air-cooled option and a hybrid cooling option were considered feasible for the GHPF. These options are considered further below.

Option 1: Air Cooling System

5.3.7 A fin-fan air cooling system is being considered to reduce the reliance on water for cooling. The closed system will require little or no maintenance.

5.3.8 Air cooling requires a large footprint (1,600 – 2,000 m^3) due to the low specific heat capacity of air. It also requires a high-power demand and exhibits a higher operating expense, and the fin fan units are also associated with potential noise issues, mainly due to the low frequency content of the turbines.

5.3.9 However, the closest residential receptor is located over 1.5 km from the GHPF and therefore the impact of projected sound levels from the fin-fan air cooling system will be low. It has also been confirmed that there is adequate space currently on site to be able to cool the electrolyser system via air-cooling alone.

Option 2: Hybrid Wet/Dry Cooling System

5.3.10 A hybrid wet/dry cooling system comprising a mix of dry air and wet evaporative cooling to provide the required cooling to the site, without affecting the existing sea water abstraction and thermal discharge limits of the power station, is an option for GHPF.

5.3.11 A hybrid wet/dry cooling system has been identified to reduce both the footprint of the cooling system and the operating expense by making use of available and existing Dwr Cymru Welsh Water raw water supply on site to provide some portion of the cooling duty. The available water will be able to provide up to 70% of the required cooling duty, with the remaining 30% being provided by fin-fan air cooling. In the hybrid cooling system, the cooling water will be recirculated and reused thus reducing the water demand.

5.3.12 Hybrid cooling is less energy intensive than air cooling alone as it offers optimisation of dry solution to reduce cooling solution footprint and power demand.

Cooling System BAT Summary

5.3.13 A firm decision on the selected cooling option has not yet been made. The environmental performance of the two remaining options is considered to be similar with the air-cooled system having the benefit of reduced water demand and the hybrid system having a lower energy consumption. Overall, it is concluded that either system would be BAT for the GHPF.

5.4 Control of Emissions to Air

Hydrogen Flare

5.4.1 Flaring has been selected as opposed to venting to reduce the global warming potential. The flare has been designed to ensure efficient combustion of hydrogen and is only expected to operate occasionally, during start up, shut down and any emergency shut down situations to prevent and avoid emissions. This is consistent with BAT requirements as set out in the EA guidance: Review of Emerging Techniques for hydrogen Production from Electrolysis of Water[12].

5.4.2 Under normal operation of the green hydrogen facility, only the pilot light would be in continuous operation, not the flare itself.

5.4.3 There is one product hydrogen storage vessel operating as a buffer tank associated with the green hydrogen plant, as outlined in Section 3.6. Note that product buffer storage is not necessarily required as hydrogen will normally be sent directly out by pipeline to Valero Pembroke Refinery, however it has been included as it will minimise the need to flare hydrogen in the event of an issue with the off taker.

5.4.4 Overall the measures designed to minimise the need for flaring combined with the use of a flare to combust hydrogen over venting where possible are considered to meet BAT.

Oxygen

5.4.5 Oxygen collected from the anode will be via a vent located at high level on the roof of the electrolyser building. The vent will be designed to ensure safe dispersion of oxygen. There is potential for oxygen from the electrolysers to be sent to an off-taker and undergo further purification, potentially improving the resource efficiency. There is sufficient land available within the revised boundary to facilitate this if needed.

5.4.6 Until such times as an end user can be secured for the oxygen byproduct venting via an appropriately designed vent is considered to meet BAT.

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[12] Review of emerging techniques for hydrogen production from electrolysis of water (publishing.service.gov.uk)

5.5 Hydrogen Purification

5.5.1 To condition the hydrogen produced, the hydrogen purification system uses deoxidisers and dehydration systems as outlines in Section 3.5. The hydrogen purification system is required to meet the agreed specification of the end user. The proposed systems do not generate emissions of air pollutants and all aqueous emissions are recycled back for re-use within the process.

5.5.2 The system requires heat within the adsorption process which is provided by heat from the hot hydrogen gas that subsequently requires cooling making efficient use of energy.

5.5.3 The purification system generates relatively low amounts of waste which are limited to the deoxo reactor catalyst and adsorber packing which require exchange circa annually.

5.5.4 The techniques selected therefore produce low emissions and waste and are designed to make efficient use of water and energy. On this basis the proposed design meets BAT.

5.6 Control of Emissions to Water

5.6.1 There will be no new continuous aqueous waste produced on site by the GHPF; aqueous waste water associated with the demineralised water supply to the GHPF will be produced in the existing Power Station demineralised water plant and will be discharged within the parameters included within the current Power Station permit. For PEM and AEL technology the ion exchange resins will be replaced and removed off site for regeneration therefore there will be no associated discharge of wastewaters from this source.

5.6.2 Water is recycled on site where possible as follows:

- The electrolyser recycles any wastewater from the process i.e. condensate is re-routed to a storage tank and reused in the demineralised water supply.
- Wastewater is also produced when using cooling tower cells. The cooling tower purge will be recycled to the inlet of the water treatment plant.

5.6.3 The techniques selected minimise the quantity of water used and are designed to reuse water where possible. On this basis the proposed design meets BAT.

Drawing 1 Site Location Plan

Drawing 2 Installation Boundary Plan

Drawing 3 Site Layout Plan

Drawing 4 Drainage Plan

Drawing 5 Process Flow Diagram

Drawing 6 Heat and Mass Balance

Drawing 7 Water Balance

Appendix A

APPLICATION FORMS

Appendix B
NOISE ASSESSMENT

Appendix C

SITE CONDITION REPORT

Appendix D
ENVIRONMENTAL RISK ASSESSMENT

PEMBROKE GREEN HYDROGEN PERMIT APPLICATION

Supporting Information

2025-07-02

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