Cleve Hill Case Team
1/18 Eagle Wing
The Planning Inspectorate
Temple Quay House
Temple Quay
Bristol
BS1 6PN

9th September 2019

Ref: 20018862

Cleve Hill Solar Park Development – Battery Storage Systems Objections

Dear Madam or Sir,

I would like to express my objection to the Cleve Hill Solar Park development based on a number of issues not previously presented. The additional main issues which I would like to bring to the attention of the Planning Inspectorate are summarised as follows:

Decommissioning and waste disposal costs for battery storage systems and redundant solar panels

Based various considerations provided in written submission, it is estimated that the battery storage systems for the proposed CHSP development may be approximately 257,126m^3. The current cost for hazardous waste disposal in the UK is about £154 per ton. It is estimated that waste disposal costs for hazardous battery storage units may be in the region of £39,597,404.

The CHSP development submitted planning application suggests that approximately 880,000 solar panels will be installed. Based on conversion factors detailed in IRENA 2016, the weight of the 880,000 solar panels is approximately 17,687tons.

Based on the current costs for hazardous waste disposal in the UK of £154 per ton, waste disposal costs for the solar panels may be in the region of £2,723,915.

Thus, based on limited information provided by CHSP, it is estimated that current waste disposal costs for the battery storage systems and solar panels may be in the region of £42,351,319.

It is my opinion that significant costs will entail in the future during decommissioning of the CHSP development and recommend to the Planning Inspectorate that a minimum financial bond is provided by CHSP in advance of any development, of a minimum of £45million to ensure sufficient funds will be available for decommissioning of the CHSP development. It is also recommended that this financial bond is reviewed annually and increased according to rising costs for hazardous waste disposal.

Human health effects of previous reported exposure model

In my previous objection report I used the ALOHA dispersion modelling tool and considered the case of a 10,000kWh battery storage system catching fire and generating hydrogen fluoride for a duration of 60 minutes, the predicted ambient hydrogen fluoride concentrations exceed the derived domestic property exposure limit by a factor of 2,444 at a distance of 4.5km and a factor of 1,333 at distance of

7.8km and a factor of 55 at a distance of 10km. A derived exposure limit for domestic properties of 0.018ppm was used.

The potential health effects as published by Public Health England are as follows:

- At ambient concentrations of hydrogen fluoride at 44ppm, predicted up to a distance of 4.5km, that at or above this concentration the general population could experience life-threatening health effects or death;
- At ambient concentrations of hydrogen fluoride at 24ppm, predicted up to a distance of 7.8km, that at or above this concentration there may be irreversible or other serious long-lasting effects or impaired ability to escape;
- At ambient concentrations of hydrogen fluoride at 1ppm, predicted up to a distance of 10km, that at or above this concentration the general population could experience notable discomfort.
- Based on the additional information published by Public Health England, I would like to reiterate that the risk to human health in a catastrophic fire event of a 10,000kwh battery storage system is very significant and foreseeable, and in my opinion not acceptable to potentially expose a large number of residents in close vicinity of the proposed development at CHSP.

Based on the foreseeable and significant human health risks and human health effects from the proposed battery storage systems for the Cleve Hill Solar Park, I would like to reiterate and recommended that any such battery storage system should be at least 15km from any population.

Potential environmental effects of Vanadium redox flow batteries

It was brought to my attention that CHSP development may use vanadium redox flow batteries, instead of Lithium Chloride based batteries.

Based on the technical information detailed by Bryans et al., 2018, I have extrapolated these values to the proposed 350MW (350,000kW) CHSP development using 200kW unit equivalents, estimating that about 1,750 of these units would be required. Vanadium redox batteries use sulphuric acid and vanadium.

It can be calculated that approximately 45,500,000 litres (45,500m3) of electrolyte of a 2 Mole sulphuric acid solution is required for the 350MW system. This equals to approximately 4,941,300 litres (4,941m^3) of concentrated sulphuric acid.

Using the same approach, it can be calculated that approximately 8,275,540kg (8,275tons) of vanadium is dissolved in the 45,500,000 litres (45,500m3) of electrolyte solution considering 1 Mole vanadium (i.e 181.88g vanadium per litre) for the 350MW system.

Recommendation- Vanadium Redox Flow Batteries

It is recommended to the Planning Inspectorate to consider that vanadium redox flow batteries are unsuitable for the proposed CHSP development due to foreseeable and significant environmental and the site specific constrains.

Leaching potential of damaged solar panels

Damaged solar panels have the potential to leach heavy metals into soil matrix (Bio Intelligence Service, 2011 and Ramos-Ruiz et al., 2017)

It is recommended to the Planning Inspectorate that CHSP development conduct a thorough investigation and assessment in accordance with UK assessment methodology in relation to mitigation measures for damaged solar panels and undertake an environmental risk assessment of the leaching potential of heavy metals from the solar panels. These investigations should consider site specific environmental constraints such as flood risk, shallow ground water and controlled water in close proximity of the solar panel locations.

Decommissioning and waste disposal costs for battery storage systems and redundant solar panels

During the recent Issue specific hearing in relation to the Draft Development Consent Order, the potential costs for decommissioning after an operational life of 40 years of the battery storage systems and solar panels have not been specifically referred to.

Based on very limited information submitted by CHSP development, I have attempted to estimate potential waste disposal costs for battery storage systems and solar panels.

Based on the drawing 'Proposed development layout, Figure 1.2, ref:2238-REP-053, dated 29/05/2018, I have estimated the surface area allocated for the battery storage system to be approximately 70,038m2. I also make reference that CHSP development refer to a number of 7,440 units in their application, albeit do not provide dimensions of these battery storage units. Due to the lack of this information, it is difficult to provide the most appropriate estimate.

However, I used the assumption that the proposed battery storage units are equivalent to 20-foot containers. Using this assumption, the footprint of 7,440 units would be 107,136m^2, exceeding the allocated surface area. However, it became apparent during the issue specific hearing on DCO that CHSP development proposed to create a bund of a height of 5.37m. Generally, bunds are calculated considering a factor of 110%. Extrapolating this allowance to the potential height of the battery storage systems within the bund, a value of 4.881m is calculated.

The assumption has been made that the 20-foot equivalent battery storage systems are stacked two at a time. Extrapolation of this assumption is that the surface area required for the 7,440 battery storage systems is 53,568m^2. Using these assumptions, it is apparent that these now fit into the allocated area of 70,038m^2.

Based on these considerations, it is estimated that the battery storage systems for the proposed CHSP development may be approximately 257,126m^3.

Lithium batteries are considered hazardous waste in the UK due to the potential of leaching heavy metals.

The current cost for hazardous waste disposal in the UK is about £154 per ton. Assuming a density of 1, it is estimated that waste disposal costs for hazardous battery storage units may be in the region of £39,597,404.

Redundant Solar Panels

In addition to the waste disposal costs for the battery storage systems, the waste disposal costs for the solar panels have to be considered. Solar Panels are also considered hazardous waste in the UK in the case no recycling facilities are available due to potential leaching of heavy metals such as cadmium, arsenic, hexavalent chromium, copper and selenium, subject to actual type of solar panel selected.

The CHSP development submitted planning application suggests that approximately 880,000 solar panels will be installed. Based on conversion factors detailed in IRENA 2016, the weight of the 880,000 solar panels is approximately 17,687tons.

Based on the current costs for hazardous waste disposal in the UK of £154 per ton, waste disposal costs for the solar panels may be in the region of £2,723,915.

Thus, based on limited information provided by CHSP, it is estimated that current waste disposal costs for the battery storage systems and solar panels is in the region of £42,351,319. These costs exclude any labour, machinery and transport for any decommissioning works.

It is my opinion that significant costs will entail in the future during decommissioning of the CHSP development and recommend to the Planning Inspectorate that a minimum financial bond is provided by CHSP in advance of any development, of a minimum of £45million to ensure sufficient funds will be available for decommissioning of the CHSP development. It is also recommended that this financial bond is reviewed annually and increased according to rising costs for hazardous waste disposal.

Human health effects of previous reported exposure model

During the open floor hearing 2, on 22nd July 2019, I presented my objections to the CHSP development due to insufficient human health risk assessments and detailed scenarios of potential exposure of the population, in an event of a catastrophic fire event, to toxic hydrogen fluoride concentrations. In this report I derived an exposure limit for domestic properties for hydrogen fluoride and the exceeding of the derived exposure limit.

I have since carried out further research and would like to bring to the Planning Inspectorate's attention the information published by Public Health England, presented in Appendix 1. The main concerns are the potential human health effects as detailed and summarised in table 'acute exposure guideline levels'. Page 9 of this document.

In my previous objection report I used the ALOHA dispersion modelling tool and considered the case of a 10,000kWh battery storage system catching fire and generating hydrogen fluoride for a duration of 60 minutes, the predicted ambient hydrogen fluoride concentrations exceed the derived domestic property exposure limit by a factor of 2,444 at a distance of 4.5km and a factor of 1,333 at distance of 7.8km and a factor of 55 at a distance of 10km. A derived exposure limit for domestic properties of 0.018ppm was used.

The potential health effects as published by Public Health England are as follows:

- At ambient concentrations of hydrogen fluoride at 44ppm, predicted up to a distance of 4.5km, that at or above this concentration the general population could experience life-threatening health effects or death;
- At ambient concentrations of hydrogen fluoride at 24ppm, predicted up to a distance of 7.8km, that at or above this concentration there may be irreversible or other serious long-lasting effects or impaired ability to escape;
- At ambient concentrations of hydrogen fluoride at 1ppm, predicted up to a distance of 10km, that at or above this concentration the general population could experience notable discomfort.

Based on the additional information published by Public Health England, I would like to reiterate that the risk to human health in a catastrophic fire event of a 10,000kwh battery storage system is very significant and foreseeable, and in my opinion not acceptable to potentially expose a large number of residents in close vicinity of the proposed development at CHSP.

I feel that the Applicant's response (document, dated 30/08/2019) provided to the Planning Inspectorate to my objection is completely insufficient by stating that 'locating battery storage at least 15 km from residential properties is not considered to be practicable in the UK'.

Potential environmental effects of Vanadium redox flow batteries

It was brought to my attention that CHSP development have recently formed a business arrangement with a manufacturer of vanadium redox flow batteries. As CHSP development have as yet not specified which type of battery storage system will be used, there is a possibility that vanadium redox flow batteries may be used.

I have researched this type of battery storage system, and would like to bring to the attention of the Planning Inspectorate, that vanadium redox flow batteries may have significant environmental risks.

Vanadium redox flow batteries are reported to be less of a fire risk compared to other battery systems such as sodium sulphur and lithium ion batteries.

I have consulted a technical paper by Bryans et al., 2018, in relation to characterisation of a 200kW/400kWh vanadium redox flow battery.

I have limited presentation of the operation of the vanadium redox flow battery to the bare minimum, but to emphasize that this type of battery uses vanadium as the carrier of the electrical charge and using sulphuric acid as electrolyte, which is pumped through the cell component.

In the example presented by Bryans et al., 2018, of testing a 200 kW vanadium redox flow battery, for the operation of this size of battery, a total electrolyte volume of 26,000L was used and was composed of 1.6Mole vanadium species in concentrated (2Mole) sulphuric acid.

Extrapolation of Vanadium Redox Flow Batteries for CHSP development

Based on the technical information detailed by Bryans et al., 2018, I have extrapolated these values to the proposed 350MW (350,000kW) CHSP development using 200kW unit equivalents, estimating that about 1,750 of these units would be required.

Sulphuric acid extrapolation

It can be calculated that approximately 45,500,000 litres (45,500m3) of electrolyte of a 2 Mole sulphuric acid solution is required for the 350MW system.

The specific density of concentrated sulphuric acid is 18.4 Moles per litre. Thus, for the operation of vanadium redox flow batteries for the CHSP development for the storage of 350MW (350,000kW) of energy, it is calculated that approximately 4,941,300 litres (4,941m^3) of concentrated sulphuric acid is required. Beside potential environmental risks, which will be further detailed below, I would like to stress that are considerable additional safety concern for the transport and transfer of these quantities to the site and at the site.

Vanadium extrapolation

Using the same approach, it can be calculated that approximately 8,275,540kg (8,275tons) of vanadium is dissolved in the 45,500,000 litres (45,500m3) of electrolyte solution considering 1 Mole vanadium (i.e 181.88g vanadium per litre) for the 350MW system.

Site Specific Risk Assessment

For the assessment of potential accidental release of the electrolyte of the vanadium redox flow battery systems the following additional site specific environmental settings have to be considered. These are summarised as follows:

- The CHSP development is located in a known flood risk zone;
- The water table is very shallow (i.e. approximately 1.4m below apparent ground level)
- There is an extensive drainage system beneath the top soil/sub base layer estimated to be 0.6m below apparent ground level;
- The soils at the site consist of clay and calciferous clay soils and sandy clay;
- There are numerous drainage ditches across the site and in close proximity of the proposed battery storage area which discharge into the main marshland basin.

Potential Environmental Release

Considering the volumes and quantities of electrolyte and vanadium required to operate vanadium redox flow batteries, there are considerable environmental risks inherent to a vanadium redox flow battery system, in the case of an accidental release. The CHSP development is proposed to be operational for at least 40 years and over this period of time an accidental release has to be considered.

A potential accidental release scenario is envisaged using a 200kW vanadium redox flow battery system as an example.

As detailed above, a 200kW vanadium redox flow battery as described by Bryan et al., 2018, uses 26,000 litre of electrolyte constituting a 2 Mole sulphuric acid solution and 1 Mole vanadium. Thus, accidental release of the entire electrolyte solution from one 200kW system would release a quantity of vanadium of 4,728,880g.

Infiltration and hydraulic conductivity

Infiltration rates and hydraulic conductivity of the top soils and subbase soils at the CHSP site are currently not known. However, Nkalai, 1983 in his theses examined similar types of sandy clay and calciferous soils and reported hydraulic conductivities ranging between 2.18 to 22.75 mm/hr.

Thus, infiltration of the very acidic electrolyte from an accidental release could reach the shallow ground water level (1.4 m below apparent ground level) of between 2 days to 26 days and could reach the field drainage system within 1 day to 11 days.

Absorption, desorption, soil buffer capacity and cation exchanges within soils matrix are complex and would require further assessment. However, it can be predicted that a significant impact to soils within the spill area and the shallow ground water and the water contained within the drainage ditch will occur from the very acidic electrolyte. The water volume within the receiving ditch is estimated to be approximately 285m^3 (based on site observations made in May 2019). It can be predicted that the pH of the entire volume of water will become extremely acidic and polluted with vanadium.

Environmental Standards Vanadium

The UK Environmental Quality Standard for vanadium in Controlled Waters ranges between 20 to 60 µg/L (dependent on the presence of $CaCO_3$).

Thus, infiltration of a significant quantity of very acidic electrolyte and a significant fraction of the 4,728,800g of vanadium contained within the electrolyte can be predicted to enter the water within the drainage ditch and shallow ground water and will predictably exceed the EQS for vanadium in Controlled Waters.

Further investigations, assessments and modelling would be required to derive calculated impact values.

Conclusions – Vanadium Redox Flow Battery Systems

However, considering the potential large volumes and quantities of concentrated sulphuric acid and vanadium required to operate vanadium redox batteries for the 350MW CHSP development, it can be stated that this type of battery system poses potentially foreseeable and significant environmental risks. In addition, considering the known flood risk of the area, the shallow ground water table at the site and the extensive field drainage systems across the proposed development area all these site-specific criteria contribute to an increase of the environmental risk.

Recommendations – Vanadium Redox Flow Battery Systems

It is recommended to the Planning Inspectorate to consider that vanadium redox flow batteries are unsuitable for the proposed CHSP development due to foreseeable and significant environmental and the site specific constrains.

Leaching potential of damaged solar panels.

Damaged solar panels have the potential to leach heavy metals into soil matrix (bio Intelligence Service, 2011 and Ramos-Ruiz et al., 2017). I have as yet not noted any clear statement from CHSP development in relation to any mitigation measures in the case of accidental damage of any of the solar panels proposed for the site.

CHSP proposes to install approximately 880,000 solar panels and operate for a period of 40 years. The assumption has to be made that the operational period, accidental damage or natural events such as hail storms and tornadoes damaging these panels may occur. Significant damage to solar panels by natural events occurred in California in 2015 and Puerto Rico in 2017.

It is recommended to the Planning Inspectorate that CHSP development conduct a thorough investigation and assessment in accordance with UK assessment methodology in relation to mitigation measures for damaged solar panels and undertake an environmental risk assessment of the leaching potential of heavy metals from the solar panels. These investigations should consider site specific environmental constraints such as flood risk, shallow ground water and controlled water in close proximity of the solar panel locations.

This report was prepared by Bruno Erasin, BSc, PhD.

Appendices

Appendix I – Public Health England. 2017. Hydrogen Fluoride and Hydrofluoric Acid (HF) – Incident Management

References

Human Health Risks

Public Health England. 2017. Hydrogen Fluoride and Hydrofluoric Acid (HF) – Incident Management

Vanadium Redox Flow Batteries

Declan Bryans, Veronique Amstutz, Hubert H. Girault and Lenoard E.A. Berlouis. Characterisa5tion of a 200kW/kWh Vanadium Redox Flow Battery. Batteries, 2018, 4, 54;

M**etal Pollution/Environmental Risks**

David M. T. Nkalai, 1983. Field Water holding capacity and hydraulic conductivity of a calcareous and a non-calcareous soil.

Environmental Agency, including Environmental Agency R&D Publication 20 (2006) “Remedial Targets Methodology: Hydrogeological Risk Assessment for Land Contamination”.

Environment Agency Groundwater Protection: Policy and Practice, Part 3 – tools (GP3). (August 2013, version 1.1).

The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2010.

Solar Panel Leaching Potential

Adriana Ramos-Ruiz, Jean V Wilkening, James A Field and Reyes Sierra-Alvarez. J Hazard Mater, 2017. 336: 57-64.

Bio Intellegence Service. Study on Photovoltaic Panels Supplementing The Impact Assessment For A Recast of the WEEE Directive. European Commission DG ENV, A project under the Framework contract ENV.G.4/FRA/2007/0067. Final Report, 14 April 2011.