Outline Soil Management Plan:

Butterfly / Glöyn Byw Solar Farm, Wrexham

Prepared for:
RWE Renewables UK

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1 INTRODUCTION

1.1 Background

1.1.1 This outline Soil Management Plan (OSMP) was commissioned by RWE Renewables UK to set out a methodology for identifying and safeguarding the soil resources (topsoil and subsoil) on land required for the construction, operation, and decommissioning of the proposed Butterfly/Glöyn Byw Solar Farm, Wrexham ('the Study Area'). This report utilises relevant information that is given in a separate '*Agricultural Land Classification and Soil Resources*' report that Reading Agricultural Land Consultants prepared in August 2022.

1.1.2 The Butterfly/Glöyn Byw Solar Farm is located to the south of Wrexham, adjacent to the A483, and between Johnstown to the west and Bangor on Dee in the East. The Study Area consists of three separate parcels of land: (i) approximately 21ha of grassland to the southwest of Wrexham (Site 1) known as the Western Array, (ii) approximately 66ha of arable and grassland to the south of Wrexham (Site 2) known as the Central Array, and (iii) approximately 43ha of arable land to the southeast of Wrexham (Site 3) known as the Eastern Array, as shown in the Site Context Plan provided in **Appendix 1**. The approximate centre of Site 2 Central Array is located at British National Grid (BNG) reference SJ340456.

1.2 Competency

1.2.1 This OSMP has been prepared by a Chartered Scientist (CSci), who is a Fellow (F.I. Soil Sci) of the British Society of Soil Science (BSSS). The author meets the requirements of the BSSS Professional Competency Standard (PCS) scheme for '*ALC*' and '*Soil Science in Soil Handling and Restoration*', which is endorsed, amongst others, by the Welsh Government, the Science Council, and the Institute of Environmental Assessment and Management (IEMA), now known as the Institute of Sustainability and Environmental Professionals (ISEP), (see BSSS PCS Document 2 and 4)[1].

1.3 Aims and Objectives

1.3.1 The aim of the OSMP is to maintain the quality and quantity of soil resources (i.e., topsoil and subsoil) at the Site in its current physical condition (e.g., soil depth, soil texture, soil structure, soil drainage status), chemical condition, e.g., pH level, nutrient status and soil organic matter (SOM) content, to maintain soil functions (see Section 1.4 below) during (i) the construction, (ii) operational, and (iii) decommissioning phases of the proposed solar farm.

1.3.2 Post-consent, the OSMP Plan will require updating in accordance with approved documentation by the appointed contractor prior to any construction commencing on-site. A detailed **Construction Phase Soil Management Plan (CPSMP)** would be submitted to the Local Planning Authority (LPA)/Determining Authority for approval before the start of construction, and this will sit alongside, or be part of, a Construction Environmental Management Plan (CEMP), or similar. Before decommissioning, a final **Decommissioning Soil Management**

Plan (DSMP) would be submitted to the LPA/Determining Authority for approval, and this would be part of, or accompany, a Decommissioning Plan or similar document. Before the end of decommissioning works, an **Aftercare Soil Management Plan** would be submitted to the LPA/Determining Authority for approval. The 'Aftercare period' refers to five years following compliance with the decommissioning condition, or a maximum period after compliance with that condition as may be prescribed by the LPA.

1.3.3 The objectives of this OSMP are to set out appropriate methodology to:

(i) Determine the location, extent and quality of in-*situ* soil resources (topsoil and subsoil) at the Site before construction (i.e., baseline soil status) by carrying out a desk-based assessment of published information on climate, geology, soils, and Agricultural Land Classification (ALC), and by carrying out a detailed Soil Resource Survey (SRS) on Site before the commencement of construction;

(ii) Determine types (units) of soil according to their resilience to damage (e.g., compaction) during soil handling before the commencement of construction;

(iii) Produce maps showing the location and extent of soil resources (topsoil and subsoil) in separate units identified in (ii) before construction starts;

(iv) Ensure vehicular traffic over the land is restricted to farm tracks, haul roads, or on agricultural land in appropriate weather conditions and soil-wetness state during the construction, operational, and decommissioning phases;

(v) Where necessary, to strip, store, and respread soil resources in appropriate weather conditions and soil-wetness state during the construction and decommissioning phases;

(vi) Produce a plan for an appropriate level and period of Aftercare following the decommissioning of the soil panels and infrastructure. This is to help ensure the agricultural land is reinstated and handed back to the landowner/farmer in its former quality.

1.4 Soil Functions

1.4.1 Following an Ecosystem Services[2] approach, soil functions[3] are general capabilities of soils that are important for various agricultural, environmental, nature protection, landscape architecture and urban applications. Six key soil functions are:

- Food and other biomass production;
- Environmental Interaction: storage (including carbon sequestration), filtering, and transformation;
- Biological habitat and gene pool;
- Source of raw materials;
- Physical and cultural heritage; and
- Platform for man-made structures: buildings, highways.

1.5 Soil Receptor Sensitivity/Resilience

1.5.1 When considering soil as a growing medium for food and biomass production (i.e., the land at the Site is mainly in agricultural production), and a habitat which supports microbial, plant, and animal life, its sensitivity to change is primarily dependent on its **resilience to structural damage** during cultivation and soil handling (i.e., soil stripping, storing in stockpiles, and re-spreading). As detailed in numerous guidelines for soil handling, including the Code of Practice for Sustainable Management of Soil on Construction Sites (2009)[4], the key to understanding soil resilience to structural damage during soil handling lies in the interaction between soil texture and soil moisture, as well as the effect of this interaction on **soil structure**.

I. Soil Texture

1.5.2 Soil texture describes how the mineral element of soil comprises a mixture of mineral particles of different size, and a different **texture class** can be ascribed according to the proportion of (according to the British Standards Institution):

- clay (<0.002mm);
- silt (0.002mm to 0.06mm);
- sand
  - fine sand (0.06mm to 0.2mm);
  - medium sand (0.2mm to 0.6mm); and
  - coarse sand (0.6mm to 2.0mm).

II. Soil Moisture

1.5.3 The amount of moisture in the soil is known to affect key soil properties[5], including:

- **soil strength** (i.e., cohesion, internal friction). This is an essential feature of soils in relation to their response to soil handling, and significantly to their resistance to fracture, compression, smearing, moulding, and compaction; and
- **soil consistency**. This is commonly used to describe the 'feel' of the soil and includes properties such as friability, plasticity, stickiness, and resistance to compression and shear. Changes in consistency are sometimes described in terms of various limits (for which there are British Standard Institute (BSI) methodologies):
  - <u>The Plastic Limit</u> (or Lower Plastic Limit), i.e., the moisture content at which the soil changes from friable to plastic and is taken to be the minimum moisture content at which the soil can be puddled. This can be measured in a laboratory under BS1377:1990 '*Methods of test for soils for civil engineering purposes'* by rolling threads of soil that shear longitudinally and transversely at approximately 3mm diameter; and

- The Liquid Limit (or Upper Plastic Limit), i.e., the water content at which soil cohesion is so reduced that the soil mass will flow when a force is applied

III. Soil Structure

1.5.4 The most important structural features of soils are the size, shape, and stability of the peds (soil aggregates), which influence how the soil is penetrated by water, air, and roots. In general terms, a soil with good structure is well-drained and well-aerated, which is conducive to the health of soil flora and fauna.

1.5.5 When a soil is handled when it is too wet (i.e., the moisture content is at or exceeds the lower plastic limit), then soil strength is reduced, and it becomes prone to structural damage, i.e., it has less resistance to compression and shear. By introducing a force, such as a mechanical excavator, the wet (or plastic) soil can lose its structure and become compacted.

1.5.6 In the worst-case scenario, a well-structured and aerated soil can become poorly structured (even massive) by soil handling when it is too wet (plastic). If it is stored in this state, it can become anaerobic, with distinctive grey colouration and associated 'sour' smell. Poor drainage and anaerobic conditions cause stress and often lead to the death of plants (crops) and soil fauna.

1.5.7 The Ministry of Agriculture, Fisheries and Food (MAFF) '*Agricultural Land Classification (ALC) of England and Wales*' system has developed a methodology for assessing the interaction between soil texture and soil moisture, and, in part, classifies agricultural land quality according to soil wetness (i.e. the interaction between soil topsoil texture, soil wetness class (WC)[6], and the number of days that the soil profile is predicted to be at field capacity (i.e., the maximum amount of water a soil profile can hold following free drainage).

1.5.8 For Soil Management Plans (SMP), the methodology for assessing soil wetness should be utilised to place the different soil types at the Site into one of three soil handling units which have different resilience (i.e., high resilience, medium resilience and low resilience) to structural damage according to their respective soil cohesion and soil strength and resistance to compression and smear at different soil moisture contents. These three categories of resilience should be related to the prevailing climate, specifically the Field Capacity Days, as outlined in Table 1.1 below.

Table 1.1: Soil Handling Units		
Soil Handling Unit	**Resilience to structural damage during soil handling**	**Soil Texture Class**
A (Green)	High	Light textured soils: sand (S), loamy sands (LS), sandy loam (SL), sandy silt loams (SZL); where fewer than 225 Field Capacity Days (FCD) (Average Annual Rainfall (AAR) less than 1000mm).
B (Orange)	Medium	Above textures where there are 225 FCD 0r more (AAR 1000mm or greater). Medium textured soils with less than 27% clay content: silt loam (ZL), medium silty clay loam (MZCL), medium clay loam (MCL), sandy clay loam (SCL); where there are 225 FCD or fewer (AAR 1000mm or less). Heady textures below (i.e., more than 27% clay content) where fewer than 150 FCD (AAR less than 700mm).
C (Red)	Low	Medium textures above where there are more than 225 FCD (AAR greater than 1000mm). Heavy textures soils with more than 27% clay content: heavy silty clay loams (HZCL), heavy clay loam (HCL), sandy clay (SC) silty clay (ZC) clay (C); where FCD are 150 or more (AAR 700mm or greater). Organic and peaty soils.

1.6 Structure of the Remainder of this Report

1.6.1 The remainder of this report is structured as follows:

- Section 2 – Soil Resource Assessment;
- Section 3 – Outline Soil Management Plan – Construction, Operation and Decommissioning Phases; and
- Section 4 – Outline Aftercare Scheme.

2 SOIL RESOURCE ASSESSMENT

2.1 Background

2.1.1 This section of the OSMP sets out the findings of a desktop study of relevant published information on climate, topography, geology, soil, and ALC information. As described in Section 1.1, this report utilises relevant information that is given in a separate '*Agricultural Land Classification and Soil Resources*' report that Reading Agricultural Land Consultants prepared in August 2022.

2.2 Desk-based Assessment of Site Characteristics and Soil Resources

2.2.1 This part of the report describes site characteristics that are pertinent to soil management, as follows:

- Climate (e.g., opportunity for soil handling in suitably dry conditions);
- Topography and gradient (e.g., to help identify potential risks of soil erosion by wind and/or water); and
- Published information on geology and soils.

I. Climate

2.2.2 Interpolated climate data relevant to the determination of the Agricultural Land Classification (ALC) grade of land and soil handling is given in Table 2.1.

Table 2.1: Interpolated Climate Data for ALC at the Butterfly Solar Farm

Climate Parameter	Data for Site 1 Western Array	Data for Site 2 Central Array	Data for Site 3 Eastern Array
Average Altitude (m) above ordnance datum (AOD)	98m	81m	26m
Average Annual Rainfall (mm)	826mm	805mm	737mm
Accumulated Temperature above 0˚C (January – June)	1369 day°	1387day°	1449day°
Field Capacity Days (FCD)	193 days	186 days	173 days
Moisture Deficit (mm) Wheat	90mm	92mm	103mm
Moisture Deficit (mm) Potatoes	77mm	80mm	94mm
ALC Grade According to Climate	826mm	805mm	737mm

2.2.3 Of relevance to soil handling, the Study Area receives an **Average Annual Rainfall (AAR)** of between **737mm and 826mm**.

2.2.4 In addition, the soil is predicted to be at field capacity (i.e., the amount of soil moisture or water content held in the soil after excess water has drained away) for between **173 and 193 Field Capacity Days (FCD) per year**.

II. Soil

2.2.5 The Soil Survey of England and Wales (SSEW) soil map of Wales (Sheet 2) at a scale of 1:250,000 and accompanying Bulletin No. 11 '*Soils and their Use in Wales*' reports that land at the Site is covered by soils grouped into two soil associations as follows: the Salop 1 association across all three sites (1-3), with a small area of Wick 1 soils present in the south-east of Site 3.

- The predominant soil association in the Study Area (i.e., Sites 1-3) is the Salop 1 Association. Soils of the Salop 1 association are characterised by reddish, fine loamy over clayey, fine loamy and clayey soils associated with fine loamy over clayey soils. Profiles, when undrained, remain waterlogged for extended periods in winter and are typically classified as Wetness Class (WC) IV. Soils can be improved to WC III with underdrainage; and

- Soils of the Wick 1 association consist of deep, well-drained, coarse loamy and sandy soils, locally over gravel. Profiles are typically well drained and assessed as WC I. the Midelney association (NSRI refence 813a) which consists of stoneless clayey soils mostly overlying peat, on low ground (i.e., >10m AOD) to the southeast of Bishton.

2.2.6 The RAC ALC report determined the presence of two soil types, as follows.

I. Soil Type 1

2.2.7 The first soil type is present across most of the three sites. The topsoil comprises heavy clay loam or medium clay loam and is typically dark brown (Munsell colour 7.5YR3/3, 10YR3/3), dark grey (7.5YR4/1) or dark greyish brown (10YR4/2).

2.2.8 The upper subsoil comprises heavy clay loam or clay which is predominantly brown (10YR5/3, 7.5YR5/3, 7.5YR4/2), reddish brown (5YR5/3) or greyish brown (10YR5/2). The upper subsoil is variably permeable and contains common ochreous mottling, indicating prolonged periods of wetness.

2.2.9 The lower subsoil comprises clay which is predominantly brown (10YR5/3, 7.5YR4/2, 7.5YR5/2, 7.5YR5/3) or reddish brown (5YR5/3). Soils within this horizon contain ochreous mottling and are slowly permeable.

II. Soil Type 2

2.2.10 The second soil type is present across a relatively small area to the south of Site 3 Eastern Array and comprises sandy clay loam to depth. Profiles consist of dark greyish brown, sandy clay loam soils to 40cm where the auger was impeded by the drought conditions. These profiles show evidence of faint mottling in the upper subsoil. Observations are likely to be borderline WC I/II, which would restrict the profiles to Grade 2 by soil wetness within the site's field capacity regime.

III. Soil Handling Units

2.2.11 With reference to Table 1.1, Soil Type 1 is assessed as being of high sensitivity/low resilience to soil handling due to the predominance of heavy clay loam topsoil (i.e., Unit C, coloured red on **Figure 1**).

2.2.12 With reference to Table 1.1, Soil Type 2 in the south of Site 3 is assessed as being of medium sensitivity/medium resilience to soil handling due to the presence of sandy clay loam topsoil. However, as heavy clay loam soils are predominant in Site 3, the Eastern Array, it is prudent to include the entire Site 3 in Unit C, i.e., with high sensitivity/low resilience to soil handling, as indicated by the colour red in **Figure 1**.

3.0 OUTLINE SOIL MANAGEMENT PLAN (OSMP)

3.1 Introduction

3.1.1 This section outlines general requirements for vehicular traffic over agricultural land, and where necessary, soil handling, i.e., soil stripping, storage, and placement/re-spreading, during the construction, operational, and decommissioning phases of the proposed solar farm.

3.1.2 Best practice for solar farm design and layout, and good practice in construction set out in the BRE National Solar Centre's (2014) '*Agricultural Good Practice Guidance for Solar Farms*' (Editor J Scurlock) should be followed[7].

3.2 General Requirements for Soil Handling

3.2.1 The quality and quantity of soil resources (topsoil and subsoil) within the Site shall be maintained by following the approach of the DEFRA '*Code of Practice for the Sustainable Management and Use of Soil on Construction Sites*' (Defra, September 2009)[8]. This is to achieve the following principal objectives:

(i) The avoidance of unnecessary damage to all soil layers, especially by compaction and smearing;
(ii) The maintenance of a reasonable degree of fissuring, drainage, and aerobic conditions in stored soils;
(iii) The reasonable replication of the original sequence of textural horizons and permeability of the soil profile when the materials are reinstated, based on a target restoration profile (i.e., the original/baseline soil profile determined in the SRS before construction begins); and
(iv) The preservation of soil biodiversity and Soil Organic Matter (SOM).

3.2.2 All soil and soil-forming materials shall be handled in accordance with the Institute of Quarrying's Good Practice Guide for Handling Soil (2021), Sheets A – E (handling soil using backacters and dumptrucks)[9].

3.2.3 All soil shall only be moved when in a dry and friable condition. For all soil types, no soil handling should proceed during and shortly after significant rainfall, or when puddles are present on the soil surface. An appropriate method for determining soil moisture content for soil handling is given in **Appendix 2**. Alternatively, the Plastic Limit (see Section 1.5 (III) above) of the different soil types/units should be determined in a laboratory to British Standard 1377: 1990 '*Methods of test for soils for civil engineering purposes*'. Soil handling should cease when the Plastic Limit is exceeded, and not recommenced until the land/soil has at least 24 hours after rainfall has ceased.

3.2.4 When a soil is handled when it is too wet (i.e., the moisture content is at or exceeds the lower plastic limit), then soil strength is reduced, and it becomes prone to structural damage, i.e., it has less resistance to compression and shear. By introducing a force, such as a mechanical excavator, the wet (or plastic) soil can lose its structure and become compacted. As described in Best Practice produced by the Institute of Quarrying (see '*Supplementary Note 4 – Soil Wetness'* given as **Appendix 2**) '*…The degree of effect due to soil handling is likely to vary between the soil textural class, structural condition, and organic matter content, the local climate and daily weather conditions, but also between the types and size of machinery used and handling practice adopted. The primary cause of compaction arises from the compression caused by trafficking by the machinery and stockpiling of soil in storage*. *Whilst some degree of remedial actions might be possible, experience has demonstrated that minimising compaction by handling soil in a dry condition is the more effective and reliable, and likely most cost-effective option.'*

3.2.5 Guidance is given in **Appendix 2** on the general timing of operations. A field-based determination of when the actual operations should start, cease or restart based upon actual soil wetness is provided. The CPSMP and DSMP should carefully consider the timing of (i) vehicles trafficking over the land and soil, and (ii) land-work and soil handling operations. The CPSMP and DSMP should provide mitigation measures to avoid or reduce damage to soil structure, especially when the soil is wet, including a method for determining when land-work and soil handling operations should start, cease and restart based upon actual soil wetness. This may include determination of the Plastic Limit of the different soil types/units should be determined in a laboratory to British Standard 1377: 1990 '*Methods of test for soils for civil engineering purposes*'[10].

3.2.6 From an '*Indicative on-average months when vegetated mineral soils might be in a sufficiently dry condition according to geographic location, depth of soil and clay content*' (Table 4.1, **Appendix 2**), the soil at the Site is predicted to be in a sufficiently dry condition as follows (Note: this is a predicted period over the year when the soil is most likely to be suitable for handling. However, guidance above for ceasing and restarting work during this period):

- Soil Handling Unit C (High Sensitivity and Low Resilience to Soil Handling): More than 27% clay in Climate Zone 1 = Late May to October

3.2.7 Throughout the period of working, restoration, and Aftercare, the operator shall take all reasonable steps to ensure that drainage from areas adjoining the Study Area is not impaired or rendered less efficient by the permitted operations.

3.2.8 The operator shall take all reasonable steps, including the provision of any necessary works, to prevent damage by erosion, silting, or flooding and to make proper provision for the disposal of all water entering, arising on, or leaving the Study Area during the permitted operations.

3.2.9 Any oil, fuel, lubricant, paint or solvent within the site shall be so stored as to prevent such material from contaminating topsoil, subsoil, soil-forming material, or reaching any watercourse.

3.2.10 Throughout the period of working, restoration, and aftercare, the operator shall have due regard to the need to adhere to the precautions for preventing the spread of plant and animal diseases'[11].

3.3 Ground Preparation

3.3.1 Before stripping agricultural topsoil (e.g., access roads, inverters, cable-routes and the sub-station), all above-ground vegetation should be cleared off Site in the areas to be stripped, so that the amount of vegetation within the topsoil strip is minimised (this is to minimise the amount of anaerobic decomposition of vegetation / organic matter that will occur within the topsoil stockpiles).

3.4 Haul Roads

3.4.1 Vehicles, e.g., heavy goods vehicles (HGV) delivering construction materials, should not be permitted to traffic over agricultural land and should be restricted to public highways, farm tracks, haul roads, and storage compounds.

3.4.2 Construction machinery such as piling machines and telehandlers should not traffic over agricultural land which is left in situ (i.e., where the topsoil has not been stripped) when the soil is too wet. This is to prevent soil structural damage due to compaction and smearing, and to avoid creating ruts/vehicle tracks at the ground surface. See '*General Requirements for Soil Handling*' above for guidance on appropriate soil moisture content for soil handling.

3.4.3 It is recommended to use temporary haul road systems for installing the solar panels to minimise structural damage to the soil. This could involve the use of a heavy-duty composite plastic trackway system on a thin layer of stone, or no stone, e.g., GroundGuards Xtreme Mats 4mx2m Large Mats[12] or SignaRoad 3mX2m Large Mats[13], or other similar geotextile material.

3.5 Soil Stripping

3.5.1 Before any part of the Site is excavated or is built upon, or used for the stacking of topsoil, subsoil or overburden, or as a machinery dump or plant yard, or for the construction of a road, all available topsoil and subsoil shall be stripped from that part.

3.6 Soil Storage

3.6.1 Bunds for the storage of soils shall conform to the following criteria:

(i) Topsoil and subsoil shall be stored separately.

(ii) Where continuous bunds are used, dissimilar soils shall be separated by a third material.

(iii) Soil Handling Unit B topsoil and subsoil with medium sensitivity/medium resilience to soil handling shall be stored in bunds which do not exceed 4m in height.

(iv) Soil Handling Unit C topsoil and subsoil with high sensitivity/low resilience to soil handling shall be stored in bunds which do not exceed 3m in height.

(v) Materials shall be stored like upon like, so that topsoil shall be stripped from beneath subsoil bunds, and subsoil from beneath overburden bunds.

(vi) All storage bunds containing soils which are intended to remain in situ for more than 6 months or over the winter period are to be grassed over and weed control and other necessary maintenance.

(vii) All topsoil, subsoil, and soil-forming material shall be retained on site.

4.0 OUTLINE AFTERCARE SCHEME

4.1.1 Following the decommissioning of the solar farm, removal of the solar panels and associated infrastructure, and restoration of land and soil to agriculture, there shall be a period of Aftercare. The Operator shall prepare a schedule of Aftercare maintenance, to include soil testing, appropriate to the target for soil restoration for a period up to five years.

4.1.2 On completion of the restoration works the restored soils will be in a fragile condition. The objectives of the Aftercare period are to:

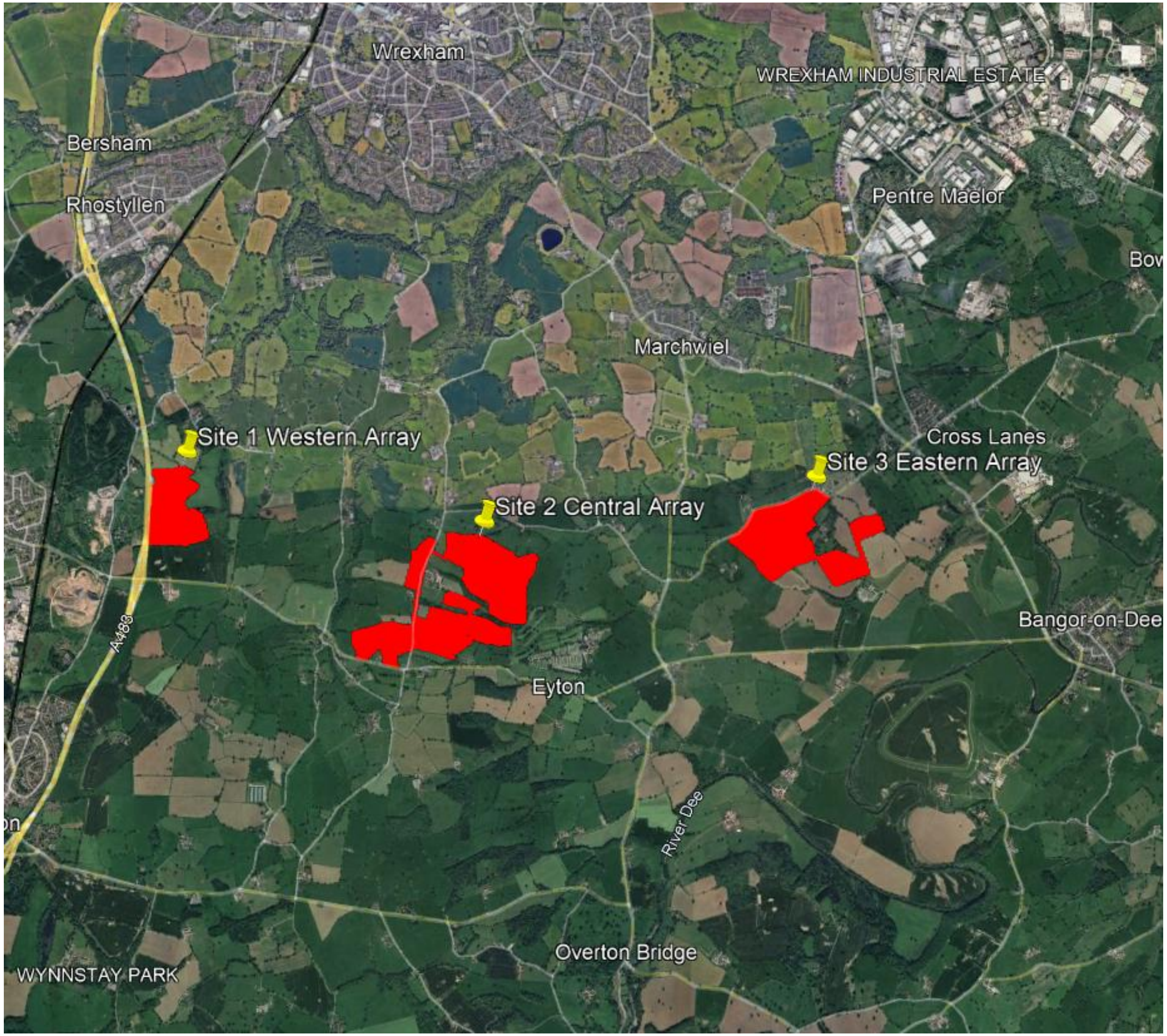
(i) Soil cultivation and establishment of vegetation cover with a good rooting system such as grass as soon as possible after reinstatement of the soils (year 1);

(ii) At the end of year 1, the land should be checked for settlement and any hollows should be infilled by scraping back the topsoil and infilling with subsoil compatible with the subsoil beneath, before reinstating the topsoil;

(iii) Soil cultivation and vegetation management (year 2-5). This is to check the condition of the soil and grass (or other crop); and amelioration work is undertaken as necessary, e.g., infilling of settlement hollows, subsoiling to improve soil structure and to correct any patchy areas of poor growth; and

(iv) Consideration of the drainage of the restored agricultural land to prevent flooding.

Figures



Key

- Study Area
- Auger Bore Location
- Soil Handling Unit 1 – High Resilience to Structural Damage
- Soil Handling Unit 2 – Medium Resilience to Structural Damage
- Soil Handling Unit 3 – Low Resilience to Structural Damage

Figure 1:
Soil Handling Units

Project Name:
Butterfly / Butterfly/Glöyn Byw Solar Farm, Wrexham

Client:
RWE Renewables UK

Project Number: **C1288**

Date: 12/09/2025

Drawn By: RWA

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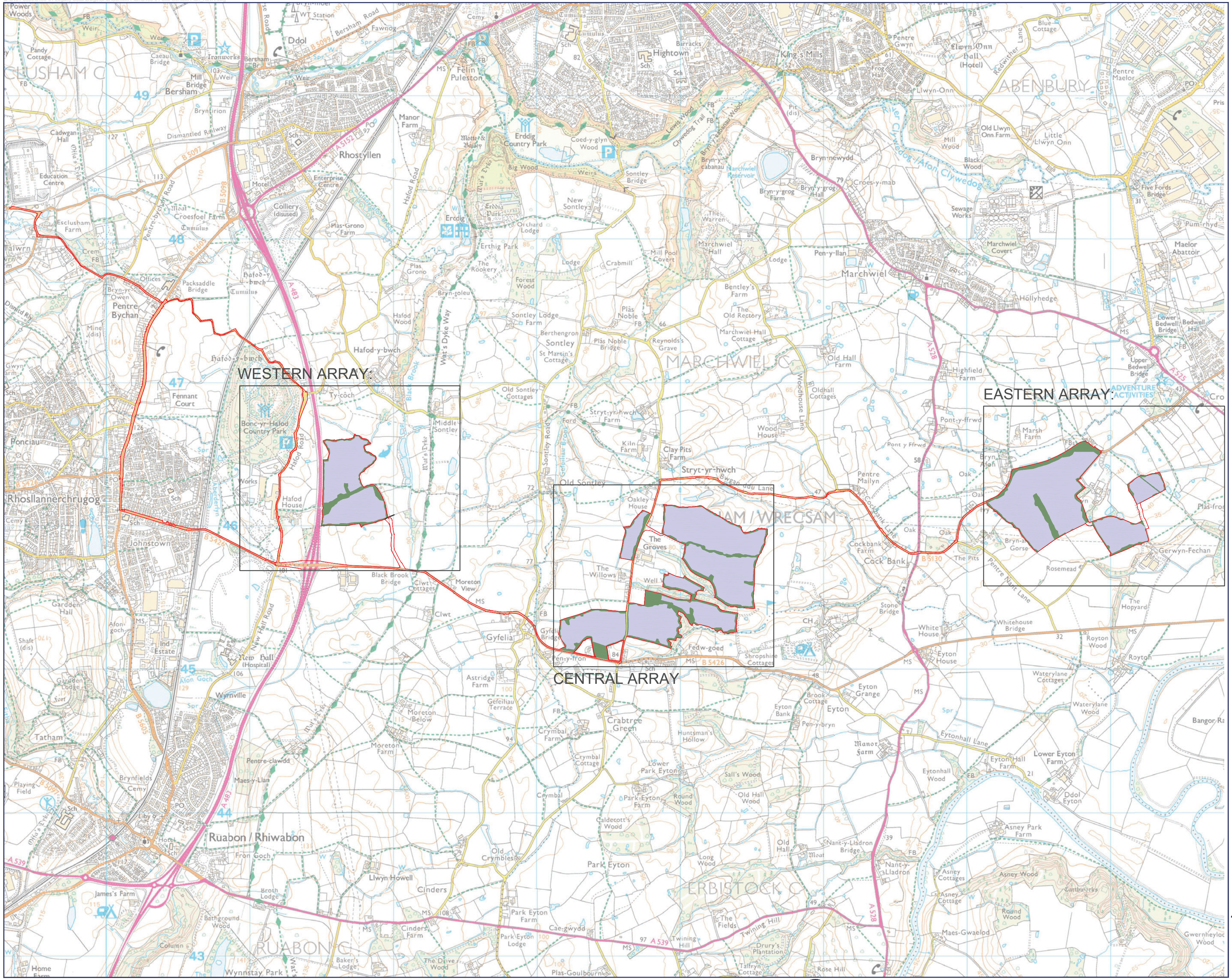
Appendix 1:
Site Context Plan



- Planning Red Line Boundary
- Wildflower / Wildlife Enhancement Area
- Panelled Area Extent

0344 8700 007

axis.co.uk

axis

Client

RWE

Project

Glöyn Byw / Butterfly Solar Farm

Drawing Title

Site Context Plan

Scale	Status
1:25,000 @A3	--

Date	Drawn	Checked
September 2025	SR	LH

Dwg no	Rev
3456-01-007	

revision: desc: date:

N

0 0.5 1 1.5 2 2.5km

Appendix 2:
Institute of Quarrying
'Supplementary Note 4 – Soil Wetness'

Supplementary Note 4
Soil Wetness

Soil wetness is a major determinant of land use, and environmental and ecosystem services in the UK. It is also a factor in the occurrence of significant compaction arising from handling soils with earth-moving machines and the practices used (Duncan & Bransden, 1986).

Relative soil wetness can range from the waterlogged to moist (mesic) or dry (xeric) depending on rainfall distribution and depth to a water-table and duration of waterlogging. In the UK, soil wetness is largely seasonal with higher evapo-transpiration rates potentially exceeding rainfall in the summer resulting in the soil profile becoming drier where there is vegetation. Whilst soil wetness is largely weather system and equinox (climate) driven, it varies with geographical and altitudinal locations, and importantly the physical characteristics of the soil profile, such as texture structure, porosity, and depth to the water-table and topography including flood risk (MAFF, 1988). The Soil Wetness Class is based on the expected average duration of waterlogging at different depths in the soil throughout the year (days per year), and can be determined by reference to soil characteristics and local climate (MAFF, 1988). The likely inherent wetness and resilience status of a soil should be indicated in the SRMP (see **Part 1, Table 2 & Supplementary Note 1**), reflecting potential risks for soil handling such as low permeability, permanently high groundwater, or a wet upland climate.

Wet soils can also be a result of other circumstances. For example, the interception of water courses, drainage ditches and field land drains. Where these occur, the provisions are to be made in the SRMP to protect the soils being handled and the operational area.

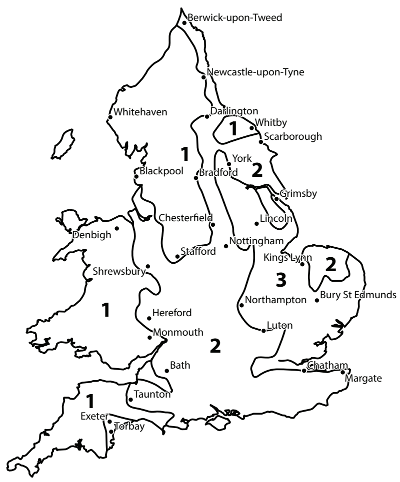
Soils, when in a wet condition generally have a lower strength and have less resistance to compression and smearing than when dry. Lower strength when soils are wet also affects the bearing capacity of soils and their ability to support the safe and efficient operation of machines than when in a dry state.

In terms of resilience and susceptibility to soil wetness, the clay content of the soil largely determines the change from a solid to a plastic state (the water content at which this occurs is called the 'plastic limit' (MAFF, 1982)). This is the point at which an increasing soil wetness has reduced the cohesion and strength of the soil and its resistance to compression and smearing.

Whilst coarse textured sandy soils are not inherently plastic when wet, they are still prone to compaction when in a wet condition. Hence, handling all soils when wet will have adverse effects on plant root growth and profile permeability, which may be of significance for the intended land use and the provision of services reliant on soil drainage and plant root growth. It may be less so in other circumstances where wet soil profiles, perched water tables and ponding are the reclamation objectives, though drainage control, for example to control flooding, may still be important in these contexts.

In cases of permanently wet soils, such as riverine sites, upland or deep organic soils where there is a persistent high water-table throughout the seasons within the depth of soil to be stripped and/or the soil profile remains too wet, a strategic decision has to be made to be able to proceed with the development of the mineral resource. This may mean alternative and less favourable soil handling practices have to be agreed with the planning authority.

Predicting & Determination of Soil Wetness
There are well established methods to predict and determine soil wetness of undisturbed and restored soil profiles (Reeve, 1994). The challenge has been the prediction of the best time for soil stripping. Models based on soil moisture deficits and field capacity dates for a range of soil textures can provide indicative regional summaries (**Table 4.1**) that can help with planning operations at broad scale but cannot be relied upon in practice for deciding operationally whether to proceed on the ground given the actual variation in weather events from year to year and within years.



	Climatic Zones		
Soil Clay Content	**1**	**2**	**3**
Soil Depth <30cm			
<10%	Mid Apr - Early Oct	Late Mar – Early Nov	Late Mar – Early Dec
10 -27%	Late May - Early Oct	Early May – Early Nov	Early Apr – Early Dec
Soil Depth 30-60cm			
<10%	Late Apr - Early Oct	Mid Apr – Early Nov	Early Apr – Early Dec
10-27%	Late May - Early Oct	Early May – Early Nov	Early Apr – Early Dec
>27%	Late June – Early Oct	Early June – Early Nov	Late May – Early Dec
Soil Depth >60cm			
<10%	Late Apr - Early Oct	Mid Apr – Early Nov	Early Apr – Early Dec
10-18%	Late May - Early Oct	Early May – Early Nov	Early Apr – Early Dec
18-27%	Late June – Early Oct	Early June – Early Nov	Late May – Early Dec
>27	Mid July – Mid Sept	Early July – Mid Oct	Late June – Mid Oct

Table 4.1: Indicative on-average months when vegetated mineral soils might be in a sufficiently dry condition according to geographic location, depth of soil and clay content

The timing of most soil handling operations takes place between April and September. Although in western (Zone 1) and central (Zone 2) areas it typically can be a later start in May with an earlier termination in August. Whilst the return to climatically 'excess rainfall' is later in the eastern counties (Zone 3) and can be as late as November/early December, there is a need to maintain transpiring vegetation to keep the soils being handled in a dry as possible condition and to establish new vegetation covers as soon as possible (on replaced soils and storage mounds). Hence, soil handling operations generally need to be completed no later than the end of September (Natural England, 2021), unless appropriate provisions can be assured.

Where data is available, more realistic local and real-time predictions can be made, however, because weather patterns and events differ between and within years, and soils can be vary locally in their condition. Experience has shown that the most practical approach for operations is to inspect the site and soils in question near to/ at the time when soil handling is to take place. Professional soil surveyors can advise on the best time for soil handling (stripping, storage & replacement) and carry out site assessments of soil wetness condition prior to the start of operations.

A Practical Method for Determining Soil Wetness Limitation

During the soil handling season (see Table 4.1 above), prior to the start or recommencement of soil handling soils should be tested to confirm they are in suitably dry condition (**Table 4.2**). The 'testing' during operations can be done by suitably trained site staff and reviewed periodically by the professional soil surveyors.

The method is simply the ability to roll intact threads (3mm diameter) of soil indicating the soils are in a plastic and wet condition (MAFF, 1982; Natural England, 2021). Representative samples are to be taken through the soil profile and across the area to be stripped. It is the best available indicator of soils being too wet to be handled and operations should be delayed until a thread cannot be formed. For coarse textured soils which do not roll into threads, a professional's view as to soil wetness and the risk of compaction may have to be taken.

Table 4.2: Field Tests for Suitably Dry Soils

Soil tests are to be undertaken in the field. Samples shall be taken from at least five locations in the soil handling area and at each soil horizon to the full depth of the profile to be recovered/replaced. The tests shall include visual examination of the soil and physical assessment of the soil consistency.

i) Examination

- If the soil is wet, films of water are visible on the surface of soil particles or aggregates (e.g. clods or peds) and/or when a clod or ped is squeezed in the hand it readily deforms into a cohesive 'ball' means **no soil handling to take place.**
- If the samples is moist (i.e. there is a sligh dampness when squeezed in the hand) but it does not significantly change colour (darken) on further wetting, and clods break up/crumble readily when squeezed in the hand rather than forming into a ball means **soil handling can take place.**
- If the sample is dry, it looks dry and changes colour (darkens) if water is added, and it is brittle means **soil handling can take place.**

ii) Consistency
First test
Attempt to mould soil sample into a ball by hand:

- Impossible because soil is too dry and hard or too loose and dry means **soil handling can take place.**
- Impossible becuase the soil is too loose and wet means no soil handling to take place.
- Possible - Go to second text.

Second test
Attempt to roll ball into a 3mm diameter thread by hand:

- Impossible because soil crumbles or collapses means soil handling can take place.
- Possible means no soil handling can take place.

N.B.: It is possible to roll most coarse loamy and sandy soils into a thread even when they are wet. For these soils, the Examination Test alone is to be used.

A Rainfall Protocol to Suspend & Restart Soil Handling Operations
Local weather forecasts of possible rainfall events during operations and the occurrence of surface lying water have been used to advise on a day-to-day basis if operations should stop (Natural England, 2021). Single events such as >5mm/day in spring and autumn months, and >10mm/day in the summer have been suggested as more precise triggers for determining soil handling operations (Reeve, 1994). However, in practice the following generic guidelines are often used:

- In light drizzle soil handling may continue for up to four hours unless the soils are already at/near to their moisture limit.
- In light rain soil handling must cease after 15 minutes.
- In heavy rain and intense showers, handling shall cease immediately.

In all of the above it is assumed that soils were in a dry condition. These are only general rules, and it is at the local level decisions to proceed or stop should be based on the actual wetness state of the soils being handled. After the above rain event has ceased, the soil tests in **Table 4.2** above should be applied to determine whether handling may re-start, provided that the ground is free from ponding and ground conditions are safe to do so.There can be extreme instances where soil horizons have become very dry and are difficult to handle resulting in dust and windblown losses. In these conditions the operation should be suspended. The artificial wetting of extremely dry soils is not usually a practice recommended but has been successful in some cases.

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