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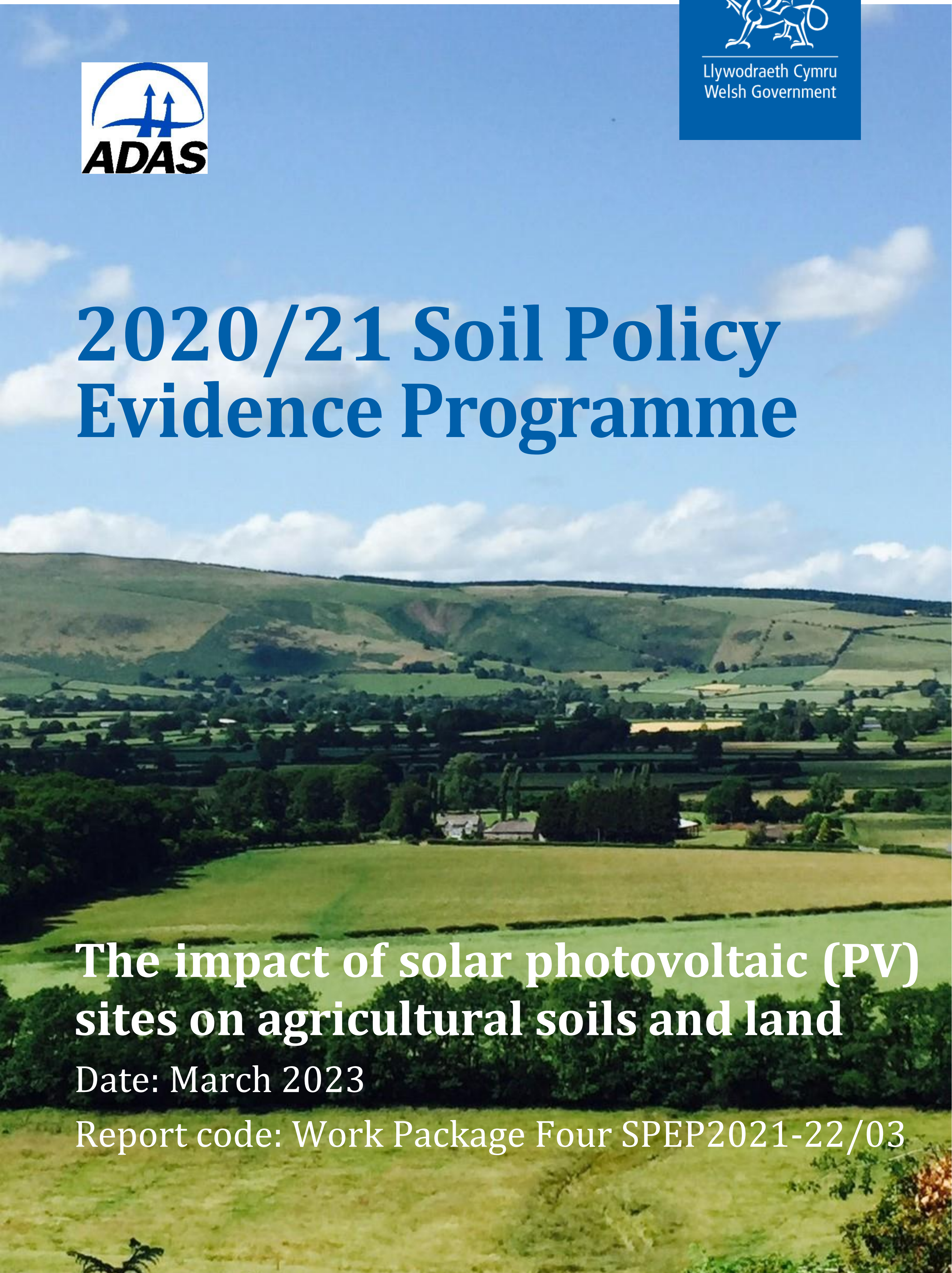
Welsh Government

2020/21 Soil Policy Evidence Programme



The impact of solar photovoltaic (PV) sites on agricultural soils and land

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The impact of solar photovoltaic (PV) sites on agricultural soils and land

Work Package Four : Summary

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ADAS

ADAS GENERAL NOTES

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EXECUTIVE SUMMARY

This report is part of an evidence-based assessment of the impact of solar photovoltaic (PV) sites on agricultural land and soil. The work, under the Welsh Government's Soil Policy Evidence Programme SPEP 2021-22/03, is to inform Welsh Government and Natural England specialists when dealing with solar photovoltaic (PV) planning applications.

- Work Package 1- Literature Review
- Work Package 2- Development and history of solar PV sites
- Work Package 3- Review of solar PV site impacts on land and soil

The literature review found that there are few in-field studies on solar PV sites, which consider the impact of the development on soil and land. There are studies on the impact of solar PV sites on microclimate, carbon cycling and vegetation management (Armstrong et al, 2016).

There has been a significant increase in projects with a generating capacity close to 50MW (BEIS Renewable Energy Planning Database June 2021). The land area of such projects (close to 50MW) is typically between 60 ha and 80 ha. The preparation of the planning application, often taking over 12 months, and process, itself taking up to 2 years, makes up a large part of the development cost.

The key impact of solar PV sites on land and soil may be caused by compaction leading to soil structural damage. The effects of soil compaction on soil structure lead to reduced permeability to water and air as well as increased surface runoff and erosion. Compaction near the surface and generally above a depth of 45cm can be alleviated. However the alleviation of deep compaction requires equipment such as a bulldozer and winged tine set to a depth to 60cm. The reversibility of soil compaction may take many years and in some cases compaction may be permanent. An assessment on the effect of compaction on the Best and Most Versatile agricultural land (land in MAFF Agricultural Land Classification grades 1, 2 and 3a) shows that the loss of high quality agricultural land is likely to occur in wetter parts of England and Wales. There may also be a loss of versatility of the high quality agricultural land in other parts of England and Wales. After decommissioning it should be possible to reverse the site to agricultural use in the context of moderate or lower quality land, providing all physical infrastructure is removed from the site. On higher quality land the success of physically reversing to the pre-construction grade will depend on the management of the soil and land from the early stages of construction through to decommissioning. A soil resources and management plan is key to the understanding of the soils present on a site. However the outcomes at decommissioning will depend on the quality of the initial soil resources and management plan, the quality of the soil handling on site and the robustness of enforcement.

There have been claimed benefits for soil properties such as increased carbon storage and improved soil structure arising from the conversion of arable land to grassland as part of the solar PV site development. The potential benefits will depend on the land use and the soil properties before any construction phase.

There are gaps in evidence, knowledge and experience on solar PV sites and their impact on soil and land. Key gaps are on recovery times of soil characteristics following compaction, the extent and depth of soil compaction on solar PV sites, interactions between the soil and piles/beams, corrosion of the piles/beams and more knowledge about soil contamination from galvanised piles/beams in the soil for 40 years.

Recommendations for future work to assist in a better understanding of the impacts of solar PV sites on soil and land include:

- A review of site work practices, in particular on soil handling, soil storage and trafficking – how current practices impact the soil and land with recommendations for any changes with potential beneficial impacts for soil and land
- Field evidence of the soil structural conditions from a baseline survey, at the pre-construction, at the post construction stage and monitoring through the operational stage in the early years
- Further investigation of recovery times of soil following compaction
- Evidence to show the impact of piles/beams in the soil over a period of 40 years and post decommissioning
- The realistic costs of decommissioning and projections
- An accepted method to identify the impact on agricultural soil and land using the ALC system (MAFF,1988). The impact on Best and Most Versatile (BMV) agricultural land and an assessment of the potential reversibility would be demonstrated.

CONTENTS

1 BACKGROUND

This report is part of an evidence-based assessment of the impact of solar photovoltaic (PV) sites on Best and Most Versatile (BMV) agricultural land and associated soils. The work, under the Welsh Government's Soil Policy Evidence Programme SPEP 2021-22/03, is to inform Welsh Government and Natural England specialists when dealing with solar photovoltaic (PV) planning applications.

Welsh Government found that there appeared to be no systematic review of the impact of solar PV sites on agricultural land, Best and Most Versatile[1+2](BMV) land and associated soils. Much of the focus of recent work was on the ecological impacts on the land through projects such as the Solar Parks Impacts on Ecosystem Services (SPIES) developed by Lancaster University and partners (2016).

Solar PV sites are viewed as a temporary development with a defined lifetime, usually 40 years. There are questions on the reversibility of sites to agriculture and the long-term impact on soil and land. There have been claimed benefits for soil properties such as increased carbon storage and improved soil structure arising from the conversion of arable land to grassland as part of the solar PV site development. Any legacy after decommissioning should be considered.

The summary draws on three work packages:

- Work Package 1 Literature Review (WP1)
- Work Package 2 Description of Solar PV site history and development stages (WP2) and WP2b Solar PV Sites in Wales
- Work Package 3: Review of Solar PV site impacts on land and soil (WP3)

This report, in Work Package 4, summarises the key finding from the above Work Packages and identifies evidence, knowledge and experience gaps. Recommendations are presented for future work needed to better understand the impacts of solar PV sites on soil and land.

[1] Land classified as Grade 1, 2 and 3a. MAFF Agricultural Land Classification Guidelines. 1988

[2] Planning Policy Wales Paragraphs 3.58-3.59 Edition 11 February 2021 and National Planning Policy Framework

2 SOLAR PV SITES, AGRICULTURAL SOILS AND LAND

2.1 Summary of Work Package 1- Literature Review

The scope of the literature review covered a review of relevant research and industry experiences related to the impacts of solar PV on agricultural land and soil, within the UK and internationally. There are few studies of solar PV sites and their impact on agricultural land and soils. Several in-field studies have considered the net environmental gain of solar PV sites.

Land use change, often from an arable use on BMV agricultural land to low-maintenance grassland, has been cited by developers in planning applications as a benefit to the soil. The Solar Parks Impact on Ecosystem Services (SPIES) is a decision support tool (Randle-Boggis et al, 2021) for use in the development and operation of solar PV sites. Armstrong et al (2016) has undertaken studies of microclimate on plots under solar PV arrays, identifying seasonal and diurnal variations in the air and soil microclimate.

Research undertaken in Colorado, USA, by Choi (2020) recognised that utility scale solar PV sites are land intensive and can have negative impacts, such as 'extensive landscape modifications that transform soil ecological functions, thereby impacting hydrologic, vegetative and carbon dynamics'. An investigation over a 7 year period reported that disturbance of the topsoil can accelerate erosion of fine soil particles and that site maintenance activities caused compaction along the panel rows.

BRE (2013) gives guidance on planning solar PV sites with examples of sites in Cornwall, often on former China clay workings. Several planning authorities have prepared their own guidance on solar PV sites (Kent County Council,2014; Maidstone Borough Council,2014).

Activities on golf course developments and mineral site developments involve soil handling, storage and soil replacement. A study of golf courses (MAFF, 1995) investigated the effects of golf course development on high quality agricultural land. The golf courses with the highest impact and greatest irreversible loss occurred where there were considerable amounts of earthmoving and landforming. The timing of soil stripping and traffic management also impacted on the soil. A study by Defra (2000) found that at the end of a 5-year statutory period the majority of mineral sites within the study had maintained their agricultural land quality.

The established code of practice for the sustainable use of soils on construction sites (Defra,2009a) covers aspects of soil stripping and storage. Pre-construction planning includes a soil resource survey.

2.2 Summary of Work Package 2- Description of solar PV history and development stages and Work Package 2b- Solar PV sites in Wales

2.2.1 Introduction

This work package set out a description of solar PV history and development stage.

2.2.2 Site Selection

Developers identify geographical areas of interest, either because it is known that there is spare capacity on the grid or the area has a high solar irradiation. Using a combination of desk-top and on-site searches, land which is free of development constraint is identified. The constraints include:

- Environmental constraints – e.g. National Parks, Local Landscape Designations
- Proximity to protected heritage sites – visual impact
- Planning constraints – e.g. Green Belt
- Topography – avoiding ground too steep for development and north-facing slopes
- Flood zones – avoiding Zone 3
- Agricultural land quality – avoiding Best and Most Versatile (BMV)
- Roads, Railways & Public Rights of Way

Following the identification of constraint free land and interested landowners further steps are undertaken which may include:

- Site technical assessment - shading, site access, ground conditions, the presence of nearby high energy consumers who may take some of the generated electricity via a “private wire”.
- Landowner negotiation – developers and owners of the land required for the scheme (including additional land for access, grid connection, etc) will enter into agreements which cover the lifetime of the project.
- Grid connection - application to the appropriate Distribution Network Operator (DNO) for a grid connection offer.
- Financial modelling – all developers have their own financial model. Many of the installation costs are formula-based but the cost of grid connection varies considerably and it is only possible to put together an economically viable scheme when all the variable costs are known.
- Planning application – the costs associated with the planning application are a large cost in the development process.

2.2.3 Solar PV History

The growth in solar PV as a whole since 2011 is shown in the graph in figure 1, taken from Solar Photovoltaics deployment in the UK- August 2021 (BEIS 2021). The graph (Fig. 1) covers all generating capacities from small, domestic, roof-mounted schemes upwards.

The data shows that there is a significant increase from 2018 in projects with a generating capacity close to 50MW (BEIS Renewable Energy Planning Database June 2021). For projects close to 50MW each development typically requires a land area of 60-80 ha. For larger projects with a generating capacity of 350MW the land area required is about 800ha.

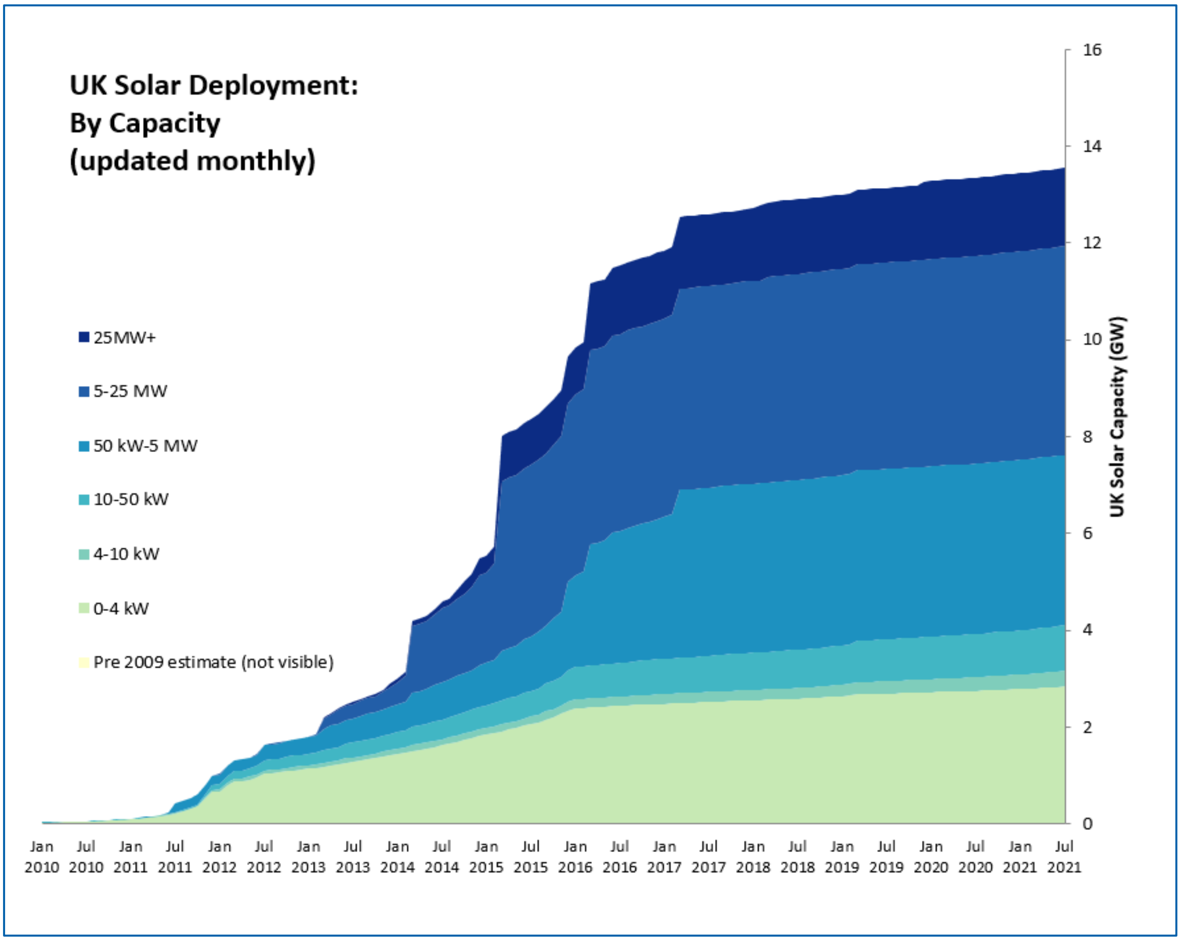

Figure 1: UK Solar Deployment

2.2.4 Site Development

Site outline plans showing details of all aspects of the proposed scheme are prepared by the developer. Each site is designed taking into account the site's technical assessment, landowner negotiation and grid connection. The solar PV development will typically include some key activities resulting in effects on soil and land, including:

1. Site levelling
2. Construction compound (either for operational life or the temporary during construction phase)
3. Site fencing and security

4. Access road/tracks
5. High voltage cabling
6. Low voltage cabling
7. String cabling
8. Earthing
9. Steel framing mounts and PV panels
10. Piles
11. Inverters and container bases
12. Substation

Solar PV developments are usually unmanned once commissioned. Regular visits may be planned by operations and maintenance staff to undertake monitoring and site maintenance. Typical activities include grass cutting, if grazing does not keep the grass at the optimum height, management of landscaping works and panel washing. The visits will generally require a 4x4 vehicle. Grass on the site is usually grazed by sheep.

Outline plans stating that decommissioning will be undertaken at the end of the operational life of the development are generally included in the planning application stage. A condition of planning permission is that a more detailed plan, usually about 6 months before the end of the operational life, is submitted to the planning authority. Decommissioning may be triggered by the end of the operational life of the development or by economic reasons or abandonment (Stantec, 2020).

Typical activities at the decommissioning phase may include:

1. Access roads may need to be reinforced to be able to carry traffic involved in the decommissioning phase
2. De-energise solar arrays
3. Dismantle panels and racking
4. Removal of piles, frames and internal components
5. Removal of structural foundations and backfill sites
6. Removal of inverter stations and foundations
7. Removal of electrical cables and conduits
8. Removal of access and internal roads
9. Removal of substation.

2.3 Summary of Work Package 2b - Solar PV sites in Wales

Work Package 2b reviewed the quantity and quality of agricultural land taken for each solar PV site in Wales by Local Authority District and by amount of supply. Data was extracted from the Department for Business, Energy and Industrial Strategy (BEIS) Renewable Energy Planning database (June 2021 update) with satellite imagery and other GIS sources to prepare site Red Line Boundaries and the Welsh Government Predictive Agricultural Land Classification Map 2.

The BEIS Renewables Database is described as being '*as accurate and comprehensive a snapshot as possible of projects*'. During the review, several sites were identified, which were not included in the BEIS Renewables Database.

The total land take was calculated to be 1521 ha and about a third of this land was mapped as Grades 1, 2 and Subgrade 3a – Best and Most Versatile land (para 3.58 of Planning Policy Wales 11 (2021)). A summary of the findings is given below.

Table 1. Quality of agricultural land in use for solar PV sites in Wales

Predictive Agricultural land Classification Grade	Area(ha)	%
1	0.0	0
2	268.1	18
3a	202.4	13
3b	660.8	43
4	254.8	17
5	116.3	8
Non-ag	15.6	1
Urban	3.0	0
Total	1521.1	100

2.4 Summary of Work Package 3- Review of Impacts on agricultural land and soil

Work Package 3 reviewed the main impacts on soil and land associated with solar PV site developments from the construction phase, through the operational phase and then the decommissioning phase.

The construction phase includes several activities such as access tracks, cabling, installation of inverters and construction of compounds, which require soil stripping, handling and storage of the soil. Soils in these areas are considered to be disturbed. Over much of the site machinery will be working and travelling on the land with the soils remaining in situ and are not disturbed.

Some key impacts on land and soil were identified at the construction phase such as damage to soil structure during soil stripping and handling and by soil compaction. Soil mixing may also result in a soil limitation and cause management problems.

Once the PV panels are in position then runoff from the panels can form rivulets or channels along the edges of the panels with a potential risk of soil erosion. During the lifetime of the solar PV site there will maintenance activities and traffic movement with a potential risk of soil compaction.

When the decommissioning phase is triggered at the end of the site's life then activities to dismantle the site commence. Pile extraction is a key activity, typically requiring a 13-ton excavator and vibrating pile driver attachment to remove one beam at a time. A void is left in the ground when the beams are removed and it is assumed that these voids will fill with soil falling into the void. Any settlement is expected to be localised and removed at the time of cultivations on the site. The impact of pile/beam pull-out on agricultural land and soil is unknown. Pile pull out may be complex with piles fracturing and requiring further work to dig out. The issue of pile corrosion and soil contamination from the potential loss of zinc from the galvanising coating on piles are further potential impacts.

An assessment was undertaken of the impacts of solar PV sites on BMV agricultural land. Reference was made to The Agricultural Land Classification (ALC) Guidelines (MAFF,1988), which provides 'a framework for classifying land according to the extent to which its physical or chemical characteristics impose long-term limitations on agricultural use'.

The assessment of land quality, after decommissioning, considered land which was disturbed, limited in extent and undisturbed land on the site where there has been trafficking. In parts of the site (e.g. the compound, access tracks, bases for inverters/substations and area of cable trenching) the soil is stripped during the construction phase, stored and then replaced at the time of decommissioning. In these areas the soil is 'disturbed' and classified accordingly within the ALC Guidelines (MAFF,1988). The soil is assessed with reference only to the textural, structural and porosity characteristics.

Where there has been trafficking, field evidence of soil compaction can include waterlogging on the surface or in subsurface horizons, low visible porosity, poor structural conditions, soil colour and rooting patterns (Batey,2009). Defra (2016) reported evidence that the number of machinery days can influence the bulk density of the soil.

An assessment is made of soil wetness (MAFF ALC Guidelines Section 3.4 and Appendix 3), an interactive limitation of the climatic regime (Field Capacity Days), the soil water regime and the texture of the top 25cm of the soil. Soil wetness influences the sensitivity of the soil to structural damage and is a major factor in determining the number of days when the soil is in a suitable condition for trafficking.

On both disturbed soil and undisturbed soil where there has been trafficking in wetter areas, there is loss of Best and Most Versatile (Grades 1, 2 and 3a) agricultural land. If unremediated, soil compaction leads to gleying in the soil and the creation of a slowly permeable layer (SPL). In slightly drier parts of England and Wales there is loss of BMV agricultural land depending on the starting depth of the slowly permeable layer. Loss of versatility of BMV agricultural land, for the soil textures considered, occurs in slightly drier parts depending on the interaction of the Wetness Class and the Field Capacity Days of the location.

The above summary of the assessment of the impact of disturbance and trafficking on BMV agricultural land leads to the consideration of the reversibility of the impacts on BMV agricultural land.

Where heavy machinery is used on construction sites there is likely to be compaction of the soil depending on the soil type and soil moisture content. The handling of soils in adverse conditions is very likely to result in damage to the soil structure.

A review of the literature on soil compaction identified that compaction in the subsoil below about a depth of 45cm is unlikely to be practical and economic to alleviate (Batey, 2009). For deep subsoil compaction below this depth a bulldozer with a winged tine can operate to depths of about 60cm.

The timescale for reversibility in the case of solar PV sites is undefined, but is taken as the point at which decommissioning is completed. There has been research work undertaken at the Swiss Soil Observatory (Keller et al, 2021) to quantify and monitor short-term recovery after prescribed compaction. Different rates of recovery are noted for soil physical properties and that after 2 years bulk density and air permeability had not recovered to pre-compaction values. Various timescales for recovery are given in published papers with 30 years (Batey,2009) and Hakansson (1988) reporting that compaction can be persistent and permanent.

There are claimed benefits of topsoil carbon capture and soil structural improvements associated with the agricultural land use change from arable use to low-maintenance grassland on solar PV sites. There is evidence from outside solar PV sites that increased soil organic matter content increases following conversion (Connant et al, 2017). However maintaining an increase in the level of soil organic content depends on continued management and Defra (2009) reported that the quantity of carbon stored in any soil is finite.

The relationship between soil structure and soil organic matter is documented (Cranfield,2001) and the beneficial effect of soil organic matter on soil structure is established.

Key points from studies on land use changes and soil carbon include:

- The initial rate of increased carbon resulting from arable to grassland reversion declines after the early years
- To maintain an increased level in soil carbon the land has to be taken permanently out of arable cultivation or rotation
- Soil organic matter is more rapidly lost than it is accumulated.

There is limited evidence specifically relating to solar PV sites to confirm the benefits to soil health. Baseline site specific soil reference values are required with long-term monitoring to provide evidence of changes and legacy in the soil health at a solar PV site over a typical lifetime of 40 years. The level of benefits will be on a case by case basis and be influenced by the land use, whether arable or long term grassland, and soil properties prior to construction.

Factors such as the disturbance of the soil at the construction phase may impinge the development of benefits through the operational phase. Even in the most successful cases (of soil carbon capture, health and structure improvement), improvements are likely to be only temporary and decrease with disruption at decommissioning and again at the return to arable cropping.

There has been work undertaken on solar PV sites to investigate the influence of shading and microclimate beneath solar PV panels (Armstrong et al, 2016). The research found that solar PV panels cause seasonal and diurnal variation in the ground-level microclimate resulting in an effect on terrestrial carbon cycling.

Soil loss in the construction phase can occur when soil is disturbed and may not be limited to the key areas of the compound and inverter/substation bases. Depending on the working practices at a solar PV site the vegetation cover may be broken and surface soil exposed. Soil erosion is known to occur under PV panels where channels are quickly formed by runoff from the panels. With more frequent heavy intense rainfall events this is a key loss of soil and soil wetness issues on sites.

The hypothesis that '*solar PV sites are physically reversible to agriculture without residual (negative) impact in the BMV and Non-BMV context'* was considered. The evidence base showed that a key residual impact on land is soil compaction. Soil compaction can vary from short term and very low impact to irreversible. The assessment of the impact on agricultural land quality was demonstrated and that in wetter areas there is loss of BMV agricultural land and in slightly drier parts of England and Wales there is generally loss of versatility of the BMV agricultural land. It may be challenging to reverse a soil profile with soil characteristics that place it in Wetness Class III at the time of decommissioning to the pre-construction condition of Wetness Class I (i.e. no slowly permeable layer present). However alleviation of deep subsoil compaction is likely to improve the movement of water and air through the soil profile and rooting of the crop, thus positively assisting in the versatility of the land for agricultural crops. The recovery timescales given in published papers varies from 18 to 30 years to being permanent. At the point of decommissioning (taken to be removal of all physical solar infrastructure from a site), there is likely to be residual compaction within the soil. There are other issues identified at the decommissioning phase that may impact on the physical reversibility to agriculture. Pile pull out may be complex with piles fracturing and requiring further work to dig out. There is also the issue of pile corrosion, which is complicated and not entirely understood (Pritchard et al 2013) and potential loss of zinc from the galvanising coating on piles and contamination of the soil.

The extent to which soil handling conditions and soil storage in planned soil bunds as part of the planning process can mitigate or remove any threats to soil and land was considered.

The identification of soil units based on soil characteristics forms part of the Soil Resources and Management Plan (SRMP). The preparation of such a plan is usually a condition of the granted planning permission. Soil handling conditions can impact on the development planning and the SRMP should be included in the pre-planning preparation and be integrated into site planning. Through the consideration of the soil resources and handling requirements any threats to soil and land can be managed to achieve the best possible outcome. There is evidence from the mineral industry that restoration back to BMV agricultural land quality can be achieved. However there is much pre-planning and planned aftercare undertaken to achieve the required standard.

Planning conditions expected for successful restoration of agricultural land to BMV and non-BMV agricultural land can be used. The preparation of an agreed Soil Resources and Management Plan submitted with the planning application, building in some of the generic planning conditions, is key to contributing to the best possible management of the soil and land. The use of the Soil Resources and Management Plan by all contractors and operators on site during the whole lifetime of the solar PV development is essential. The demonstration of realistic costings and guaranteed available funds or other support to undertake a decommissioning plan at the end of the solar PV development underpins the restoration of the site to the required agricultural land quality.

3 EVIDENCE/KNOWLEDGE/EXPERIENCE GAPS

3.1 The work packages undertaken have identified gaps in evidence, knowledge and experience and are given below:

- Field evidence of the soil structural conditions on solar PV sites from a baseline survey, at the pre-construction, at the post construction stage and monitoring through the operational stage in the early years
- Evidence of the extent of run-off from PV panels and possible influence of soil type and climatic regimes
- The longer term benefits of soil organic matter increase following land reversion on solar PV sites (it is not exclusive to solar PV sites) and the impact on soil structure after 40 years life and beyond.
- The experience of pull out of piles/beams on soil in terms of void filling, soil mixing and localised settlement
- The experience of corrosion and fracture of the piles/beams in different soil types and climatic regimes
- There is some knowledge on the interaction of pylons with the soil environment (Cranfield University, 2013), but there is a knowledge gap on the impact of close spaced galvanised piles/beams in the soil over a period of 40 years
- Experience of working practices on a range of soil types and climatic regimes and any best practice
- Knowledge on different site layouts, their impacts on microclimate beneath the solar PV panels and soil characteristics. Recent work in the Netherlands (TNO, 2021) has reported on the impact of east-west solar panel orientation and considered whether changes in the design can mitigate the deterioration of soil quality
- In the UK, most developers propose that the grassland on solar PV developments may be used for sheep grazing. The Symbizon project (TNO, 2022) is a 4-year research project combining a solar farm with strip farming. Knowledge of site layouts and alternative cropping should be investigated.

4 REPORT OF A VIRTUAL WORKSHOP SEPTEMBER 2021

4.1 Attendance

A virtual workshop, hosted via MS Teams, was organised for 2nd September 2021. For representation by the solar industry, ADAS approached Solar Energy UK, a trade association with over 230 member companies; Lancaster University, authors of the SPIES tool for assessing solar proposals; and the Department for Business, Energy and Industrial Strategy, BEIS. Also invited were agricultural land and soils experts from Welsh Government, Natural England and third parties.

4.2 Agenda

- Purpose of workshop
- Context of research project
- Initial research findings
- Input from solar developers
- Input from Department for Business, Energy and Industrial Strategy (BEIS)
- Ongoing research
- Roundtable discussion of key questions:
    a. What benefits do solar PV sites offer to agricultural soils and land?
    b. How do soils interact with the wider ecological benefits of solar PV sites?
    c. What risks do solar PV sites pose to agricultural soils and land? And what is an acceptable risk level to tolerate?
    d. What mechanisms or barriers are there to reducing risks during the installation, operation and decommissioning?
    e. What conditions should be met for a successfully restored site? Does this differ for higher quality agricultural land compared to poorer quality agricultural land?
    f. How realistic is the claim that solar PV sites on greenfield sites are a 'reversible' loss of agricultural land? Is solar being used as a precursor to permanent development down the line? Or successive solar developments?
    g. How long should planning permission be granted for? Technology changes so how many sites will be operational in 40 years' time? Risk of derelict sites.
- Wrap up

4.3 Summary of outcomes

As reported in the Literature Review (Work Package 1), the workshop largely developed into a round table discussion. There were few specific outcomes, but it was useful to this review to hear a broad spectrum of voices. The workshop was informed that Solar Energy UK is to provide agricultural land and soils input into a forthcoming industry guidance document. A good number of solar related references, papers and industry experience were exchanged. These led to new avenues of enquiry which were included in the literature review and have informed later work. Detailed responses to the key questions posed are set out in the section below.

4.3.1 Context

The study is being undertaken in a technical context rather than a policy review, sponsored by the Welsh Government team responsible BMV land protection policy in Wales and for assessing solar sites through the planning system. The purpose of the study is to ensure that the team is using the best available evidence base for making these decisions and it is being undertaken jointly with Natural England. There are four work packages:

- Literature review
- Industry overview - looking at how solar PV sites are set up from inception to decommissioning
- The impact of solar PV on land and soil
- Summary and recommendations

Some attendees who had been involved in a recent planning inspectorate case reported that the inspector was particularly interested in the impact on soils but concluded that there was little evidence to reach strong conclusions.

4.3.2 Literature review

A summary of the findings of the literature review was presented. The full report was subsequently submitted under Work Package 1. The following key points were made:

- Development is widely considered to be a temporary change of land use and reversible
- There is very little comprehensive evidence base
- There are papers on the SPIES project developed by Lancaster University and the University of York and other stakeholders to develop a decision support tool to enable the management of solar parks for environmental benefits
- Lancaster University has also undertaken research on the microclimate under solar PV arrays and the impact on above ground plant biomass and diversity. The work aims to optimise solar park design and management while maximising delivery of ecosystem services
- A study[3] of recovery times after decommissioning made a comparison between mining activity where recovery time scales are in the order of 50 to 100 years and solar PV developments where times are thought to be a quicker – but the study concluded that further work was required
- The workshop discussion queried evidence available from outside the UK and the chemical impact on soils – e.g. cadmium and lead. References were made to other work which could be included in the Literature Review including a soil sampling study of 10 solar sites by Lancaster University which will be reported in the BGS Journal, historical work in Japan and France and comparison with land restoration on golf courses.

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[3] Turney D and Fthenakis V. (2011). Environmental Impacts from the installation and operation of large-scale solar plants. *Renewable and Sustainable Energy Reviews 15 (2011), 3261-3270*

https://www.bnl.gov/pv/files/pdf/229_rser_wildlife_2011.pdf

4.3.3 Feedback from solar industry representatives

The industry body, Solar Energy UK, was currently developing a best practice guide for solar build which is to look for environmental impacts. This was due to completed and published by the end of 2021. This report[4] has now been published. The stated aim of this report is to give best practice guidance on the design, construction and operation of solar farm projects to support ecology and deliver other benefits associated with 'multiple land use'.

The management of the soil resource is not the main focus of the report. However there is reference to the use of a soil management plan and some limited broad non-technical guidance for soil resource management. [It should be noted that in the final bullet point on page 39 the following guidance was noted *'soil monitoring will check soil consistency following rainfall, to ensure it has not dried below the plastic limit'*. The *'not'* needs to be deleted from this guidance so that it reads '*soil monitoring will check soil consistency following rainfall, to ensure it has dried below the plastic limit'*]

There was a discussion about whether the guidance would cover the timing of the construction phase as there was concern about the structural damage done to soils as a result of compaction during wet weather, especially on clay soils. It is not in the best interests of the installers to operate during wet weather, but it was agreed that more direction from LPAs should be provided to ensure that commercial interests did not over-ride this concern. It was not clear how this aspect would be covered in Solar Energy UK's forthcoming guidance. It may be that timescales could be imposed similar to those imposed on developers by ecologists in relation to protected species like Great Crested Newts or ground nesting birds. The level of detail the guidance would include on best practice in relation to different soil types was unknown. It was also suggested that asset owners and developers set up a small test area where some panels are erected and trenches dug and then decommissioned to show the impact.

The issue of the impact of panel mounting foundations both at installation and decommissioning was raised and the circumstances queried under which obtrusive (e.g. concrete) piles are used rather than unobtrusive (e.g. screw or percussive piles). It was in the developer's interest to use techniques that are easily reversible to minimise work at the decommissioning stage.

There remained concerns about piling and the timing of installation activities with unanswered questions on these issues.

The use of battery storage associated with solar PV is increasing and will lead to more areas of concrete hardstanding.

The depth of trenching and management of soil removed were other issues discussed. Planning applications often provided inadequate detail on these issues.

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[4] Solar Energy UK (2021). Natural Capital Best Practice Guidance. Increasing biodiversity at all stages of a solar farm's lifecycle. https://solarenergyuk.org/wp-content/uploads/2022/05/NCBPG-Solar-Energy-UK-Report-web.pdf

4.3.4 Input from Department for Business, Energy and Industrial Strategy (BEIS)

It was noted that there was a need to strike a balance between ensuring that there are routes for considering environmental concerns and local residents views within the planning system, while at the same time recognising the need to deploy more solar to help meet net zero targets and to decarbonize the electricity system. BEIS was fully aware of the need to protect BMV land and that there was evidence that solar schemes can be beneficial to the environment and biodiversity.

4.3.5 Ongoing research

The workshop heard of a research project being undertaken by Lancaster University that is due to be reported in the Summer of 2023, involving 35 different solar farms in England and Wales. This is to take soil samples from both between and under panels and, where accessible, some of the land under the same ownership but still being farmed. These will be used to compare soil carbon storage, mineral nutrients and pH. The study was also looking at the physical characteristics of the soil.

There was also another Lancaster University study due for imminent publication[5].

A query was raised about the mapping of BMV land and the comment made that ALC often bore little relationship to the quality of the soil for farming. The workshop was informed by Welsh Government that the ALC system was developed in 1988 and did bear a relationship to soil quality for farming. The predictive agricultural land classification map which has been produced for Wales has been tested extensively with farmers and other land users and in general it was thought to be an acceptable match in terms grade and land use.

It was generally noted in discussion that Wales is ahead of England with regard to currency of ALC mapping. It was also generally noted that land use and climate change can impact on ALC.

4.3.6 Report on roundtable discussion of key questions as set out in the agenda

Benefits of solar PV sites to agricultural soils and land:

- No disturbance to soils for the duration of the solar scheme (typically 40 years)
- Potential increase in biodiversity (depending on landscape management)

Wider ecological benefits:

- Movement away from sprayed, non-biodiverse, non-organic, monoculture
- Development of fungal and microbial networks
- No soil disturbance arising from ploughing
- Phosphate retention
- Need for more research information on potential ecological benefits

Risks posed by solar PV sites to soils and land:

- Too much trenching
- Leaching of toxic material from batteries
- Introduction of concrete to site (for fencing posts, hardstanding areas, etc)

[5] Solar Energy UK (2022). A Standardised Approach to Monitoring Biodiversity on Solar Farms

- Level of risk is different for different soil types. Inadequate allowance currently made for vulnerable soils – need for guidance from soils experts
- Wet build period resulting in compaction
- Fencing may be inappropriate – Local Planning Authority (LPA) should specify fencing type to minimise soil damage
- Lack of understanding about soils best practice amongst developers. Environmental best practice guidelines are currently focused on biodiversity only
- Inadequate soils management planning
- Inadequate decommissioning statements may result in failure to return land to pre-development condition
- Failure to realise environmental benefits as a result of maintaining grassland beneath panels, although this may be neutral from an environmental perspective if the surrounding land is also maintained as grassland
- Concrete footings for palisade fencing

<u>Mitigation of risks</u>:

- LPAs should request comprehensive soil management and decommissioning plans as part of the planning application. Failure to meet minimum standards should result in rejection of application. LPAs may require guidance on the structure and content of plans
- LPAs should request more detailed decommissioning statements which are specific to the site soil types (good examples available in the United States where developers must submit a review of the decommissioning plan after 5 years and then a final closure plan)
- There should be greater clarity over the decommissioning bond arrangements (including the amount and any implications on the lease) which should be reviewed and approved by the LPA

<u>Site restoration</u>:

- The industry view is that solar PV sites should be fully reversible to agriculture and not viewed as a precursor to further development and potentially permanent change
- Correctly managed development of solar PV sites may be viewed by local residents as more acceptable than residential development

<u>Timescales for planning consent</u>:

- Industry representatives were clear that 40 years is necessary in order to meet financial modelling targets. This was not challenged by anyone else present, but this might have been due to lack of time at the workshop.

5 SOLAR PV SITE TRENDS- UPDATE 2022

5.1 Introduction

A review of the latest available data (including the Department for Business, Energy and Industrial Strategy (BEIS) Renewable Energy Planning Database) has been undertaken to identify any trends with regard to the scale of Solar PV schemes submitted for planning consent over time, with a view to commenting on the potential impact on BMV land.

5.2 Source of data

The statistical information presented in this section is derived from the BEIS Renewable Energy Planning Database (July 2022 update). The Database tracks the progress of UK renewable electricity projects over 150kW through the planning system. A scheme generating 150kW requires about 1200m² and would typically be a roof-mounted scheme on, for example, a large commercial building. 150kW is very much at the lower end of the scale for ground-mounted schemes, where the generating capacity is usually quoted in MW (1MW = 1000kW) and this analysis of the BEIS Renewables Database refers to ground mounted solar PV schemes with >1 MW capacity. The database provides as accurate and comprehensive a snapshot of projects as possible from the initial submission of planning applications to the final commissioning and operation. The database is updated during the month following the end of each quarter.

5.3 Relationship between generating capacity and land take

For the purposes of the analysis covered in the following paragraphs, a direct relationship is assumed between generating capacity (as reported in the BEIS database) and land take. There will be variations between the land take required for schemes of the same generating capacity due to differences in (a) layout, (b) land slope/orientation, and (c) panel technology (use of dual-facing or horizontal-axis tilt panels will increase generating capacity) but in most circumstances generating capacity is a good indicator for land take. For the purposes of the Industry Overview report for Work Package 2a (November 2021), it was assumed that 1 MW of generating capacity on average equates to 4.5 acres / 1.82 hectares of land although it was noted that this figure, which is widely used across the sector, does not necessarily take account of recent increased panel efficiencies.

5.4 ALC grade at operational sites

The report on Solar PV Sites in Wales for Work Package 2b (10/10/2022) did include an ALC analysis of operational sites in Wales and the finding was that 31% of land used is BMV. For context, about 10-15% of land in Wales is BMV according to the Predictive ALC Map (version 2, 2019).

The methodology used for Work Package 2b was to use satellite imagery to map individual operational sites, essentially drawing a 'redline boundary' around the visible scheme fence line, to assess potential cumulative BMV loss through comparison with the predictive ALC model undertaken by ADAS for Welsh Government as part of a separate project.

However, this analysis was of operational sites and was based on the June 2021 BEIS Renewable Energy Planning Database. It therefore excluded any schemes currently in the planning system or consented but not yet built/commissioned at the time. Should Welsh

Government want to investigate this issue further and update the Work Package 2b findings to include schemes which have become operational since June 2021 and/or consented schemes which have not yet been built, this would be an additional piece of work.

5.5 Evidence of trends in scheme sizes

As reported in the Industry Overview for Work Package 2a (November 2021) Table 2.5, new operational schemes across the UK peaked at 9.8 MW in 2014 and has dropped since then. This resulted from the closure of the Renewable Obligation Certificate scheme and the exclusion of solar PV from the replacement Contracts for Difference scheme. However, this finding does not take account of a trend towards bigger schemes which has emerged since about 2018 because very few of these have been commissioned yet. Table 2.7d from Work Package 2a report is copied below and shows the significant increase in projects in Wales with a generating capacity close to 50 MW (Data source: BEIS, 2021a) - but usually no higher because of the ceiling for schemes dealt with under the Town and Country Planning Act in England. This development arises from (a) tighter project margins forcing developers to seek economies of scale, and (b) saturation of Distribution Network Operators' (DNOs') 11 kV and 33 kV networks resulting in applications to connect to higher voltage lines, which is only economically viable for bigger schemes. The Work Package 2a report also included some details about 'super large' solar PV schemes, including the Mon Solar 300+ ha scheme in Anglesey.

Table 2: Wales >1MW Solar PV schemes applications submitted 2010-2021 (from Work Package 2a report)

Year	Number	Mean MW	Median MW
2010	2	1.3	1.3
2011	5	3.6	3.9
2012	13	8.0	7.4
2013	28	9.9	8.0
2014	38	7.2	5.5
2015	67	5.1	5.0
2016	2	29.0	29.0
2017	1	1.0	1.0
2018	4	22.5	19.5
2019	5	3.4	2.0
2020	4	33.5	35.0
2021	6	29.1	21.5

To provide an update on this scheme size, the BEIS Renewable Energy Planning Database (July 2022 update) has been reviewed and scheme applications grouped into a range of generating capacities, as shown in the tables and graphs below. This analysis includes all planning applications with a view to capturing any emerging trends. As a result, it will include some schemes which have been withdrawn or not gained consent. Numbers are shown for both Wales and England to provide comparative data.

Table 3: Wales - number of >1MW ground-mounted solar PV schemes applications submitted 2010-2022 grouped by generating capacity

Installed Capacity Range (MW)	Year 2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022*	Grand Total
1 - 10	2	5	10	19	33	65	1	1	2	5	2	5	2	152
10 - 20			3	7	4	2								16
20 - 30				1					1		1	2	1	6
30 - 40				1							1		1	3
40 - 50					1		1							2
50+									1		1	1	1	4
Grand Total	**2**	**5**	**13**	**28**	**38**	**67**	**2**	**1**	**4**	**5**	**5**	**8**	**5**	**183**

Table 4: England - number of >1MW ground-mounted solar PV schemes applications submitted 2010-2022 grouped by generating capacity

Installed Capacity Range (MW)	Year 2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022*	Grand Total
1 - 10	23	88	145	150	247	429	17	5	10	12	23	41	22	1212
10 - 20		1	34	72	128	14	1		1	8	13	28	6	306
20 - 30			4	15	27	12		1	1	3	11	23	22	119
30 - 40			3	3	10	7		1	1	4	6	15	7	57
40 - 50			3	6	6	4				11	27	69	40	166
50+									1		1	1	1	
Grand Total	**23**	**89**	**189**	**246**	**418**	**466**	**18**	**7**	**14**	**38**	**81**	**177**	**98**	**1864**

Figure 2: Graph showing number of >1MW ground-mounted solar PV schemes applications submitted 2010-2022 grouped by generating capacity in Wales

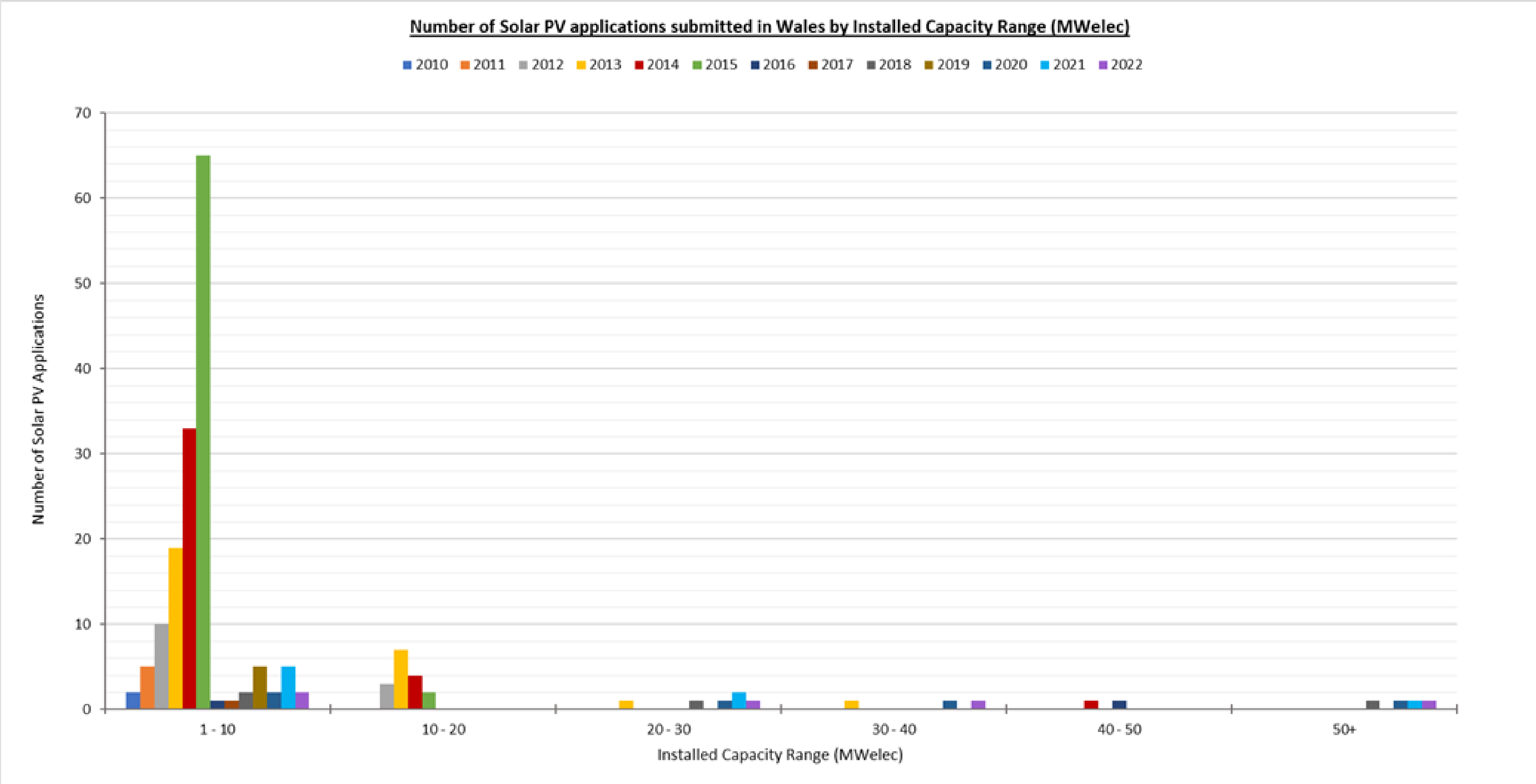
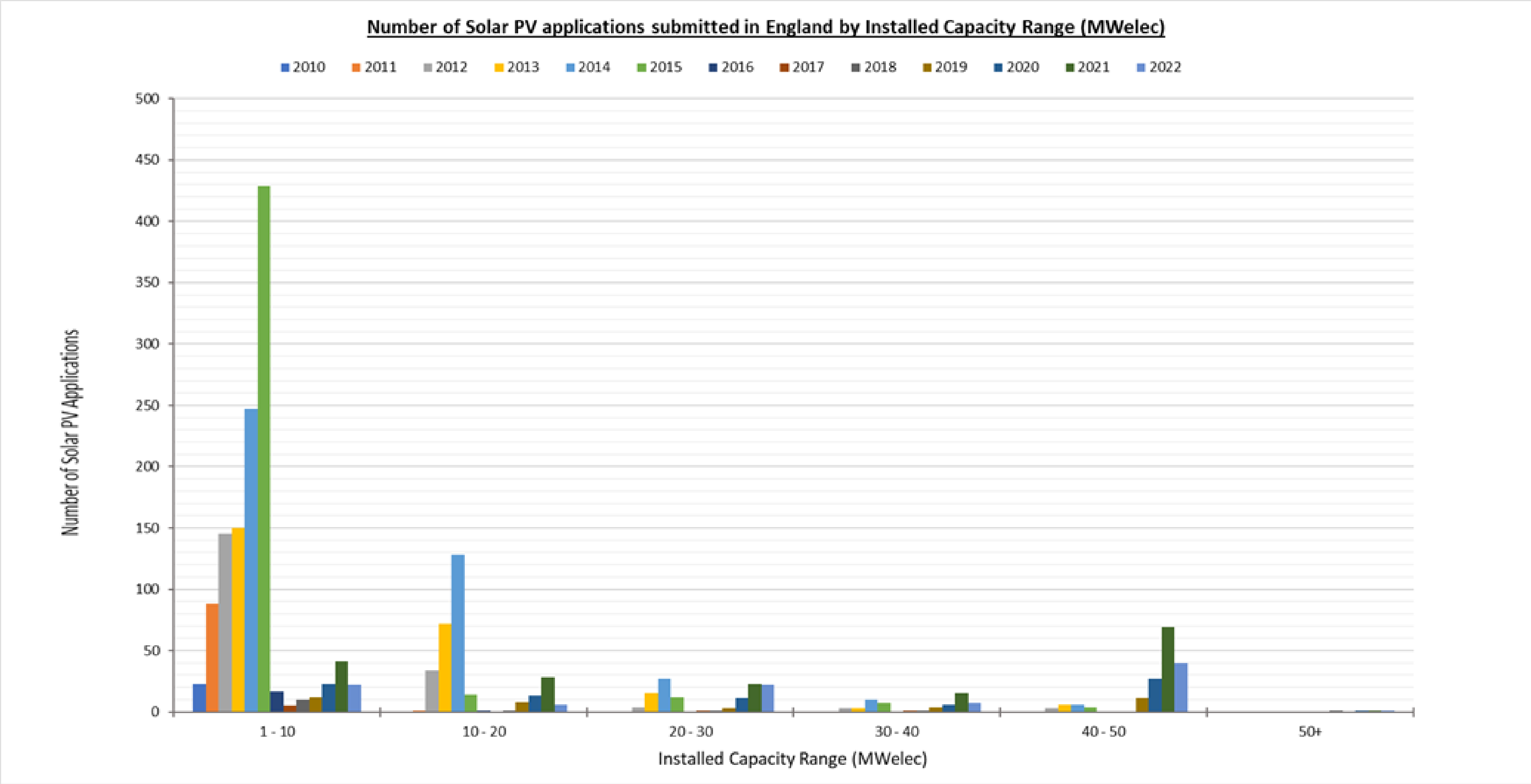


Figure 3: Graph showing number of >1MW ground-mounted solar PV schemes applications submitted 2010-2022 grouped by generating capacity in England



6 RECOMMENDATIONS FOR FUTURE WORK TO FURTHER AN UNDERSTANDING OF THE IMPACTS OF SOLAR PV ON SOIL AND LAND

The following recommendations for future work to further an understanding of the impacts of solar PV on soil and land are given:

- A review of site work practices in particular on soil handling, soil storage and trafficking – current practices and the impact on soil and land with recommendations of any changes and beneficial impacts for soil and land
- Further investigation of recovery times of soil following compaction
- The impact of piles/beams in the soil over a period of 40 years and post decommissioning.
- Further study into the interaction of soil and galvanised supports
- An accepted method to assess the impact on agricultural soil and land using the ALC system (MAFF, 1988). The impact on BMV agricultural land and an assessment of the potential reversibility would be demonstrated.
- Capture of agricultural land quality data for individual sites and a publicly available database with site details
- Further consider different site layouts, their impact on the microclimate and monitor soil characteristics
- The impact of re-powering solar PV developments beyond a typical 40-year period on the soil and land.
- Analysis of ALC Grade and BMV land take for developments that have been constructed or been awarded planning permission since the date of those visible on the satellite images available during the Work Package 2b study in June 2021.

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APPENDIX 1 PROJECT BRIEF

Soil Policy Evidence Programme SPEP 2021-22/03

The impact of solar photovoltaic (PV) sites on soil and agricultural land quality.

VERSION 2 (Draft)

Introduction:

Solar photovoltaic (PV) sites started commercial distribution in the UK in 2007. The number of solar photovoltaic sites in the UK has increased from c. 1700 in 2010 to just over one million in 2019 https://www.statista.com/statistics/418830/number-of-solar-photovoltaic-installations-uk/.

It appears there has not been any systematic review of the impact of these sites on agricultural land, Best and Most Versatile (BMV) land and associated soils. The SPIES project is useful background though soil does not feature heavily https://www.lancaster.ac.uk/spies/. Similarly, the Armstrong *et al* (2016) paper: *Solar park microclimate and vegetation management effects on grassland carbon cycling* https://iopscience.iop.org/article/10.1088/1748-9326/11/7/074016 is useful background.

Solar PV sites can involve significant soil disturbance in installation, operational phase and decommissioning. A recent proposed 34ha site in Wales involved 70,000 solar panels with 140,000 piles driven into the soil to 1.8 metres, 1.75km of access track and 3.5km Security fencing (boundary measurement), plus associated cabling. Because solar PV energy is relatively new, there are no UK examples of decommissioned sites.

There are questions on the reversibility of these sites back to agriculture and the longer term impact on associated land and soil. There are claimed improvements to some soil properties (e.g. increased carbon storage and improved soil structure). However, are these simply just short term for the period of the scheme?

The impact of mineral sites (e.g. sand and gravel extraction / restoration) is reasonably well understood and with field experience. This is not the case for solar PV sites, partly because the decommissioning timescales are long (c40 years) and the evidence does not yet exist. Can parallels could be drawn with other developments such as golf courses, gas pipelines, and pylons. Similarly, are there parallels with horticultural activities such as grubbing out orchards and glasshouse removal? What impacts do these have on soil, how are effects mitigated and how successful are restorations?

This review is to provide an evidence based assessment of the impact of solar PV sites on agricultural land, Best and Most Versatile (BMV) land and associated soils. The scope of the study should be within the UK but look to international experience where possible. The study will inform Welsh Government and Natural England specialists when dealing with solar PV applications.

The review could be used as evidence at planning appeals. Consequently, clarity and accessible is really important, despite the likely complexity of some technical content.

It is anticipated the work will form 4 work packages (WPs):

Work Package 1: Literature review

This work package will:

1. Identify and review any relevant research or experience related to impacts of solar PV developments (published or anecdotal) on land and soil, within the UK or internationally.
2. Identify and review any relevant research or experience, related to (e.g.) golf courses, glasshouse removal, grubbing out of orchards or similar developments / activities (published or anecdotal) on land and soil, within the UK or internationally.
3. Identify and review the key research and experience relating to mineral developments on land and soil, within the UK and internationally.
4. Host a virtual workshop with key soil specialists in the area and record key findings. The key outputs from this need to be recorded as part of the contract.
5. Summarise key findings in a clear and accessible format.

Work Package 2: Description of Solar PV site history and development stages

This work package is intended as a short and simply a statement of facts, rather than in depth interpretation:

1. Provide a summary history of solar PV sites development in the UK. This should include date introduced, number of sites over time and basic explanation of how solar PV sites work. It would be useful to know approximately how many applications there have been (split by UK country), some information on range of site size, preferred types of location, and whether cumulatively large amounts of BMV are likely to be involved. Is the average size of sites increasing?
2. Identify and summarise the main interventions to land and soil with solar PV sites at installation (e.g. pile driving, panel installation, cable laying, track-laying & fencing). Averages (e.g.) of piles / ha or metres of buried cable / tracks / ha would be useful as context. Use of case studies could help. It will be important to summarise the potential levels of disturbance and any differences between different types of site.
3. Identify and summarise the potential benefits and threats to land and soil during the operational phase of the site. Claimed benefits are (for example) topsoil carbon content increases and soil structure improvements.
4. Identify and summarise the main interventions to land and soil when decommissioning sites (e.g. soil disturbance linked with equipment removal).

Work Package 3: Review of Solar PV site impacts on land and soil:

This Work Package is the main review of impacts. It will largely be based on WPs 1 & 2.

1. Review and summarise the main threats to soil and land associated with solar PV site developments. This will need to assess commissioning and decommissioning phases. Assessment of impacts on BMV land - and its reversibility - will be very important.
2. Review and summarise potential effects (positive and negative) on soils during the active phase of the site. Claimed benefits are (for example) topsoil carbon content increases and soil structure improvements. Are such claims realistic and are they only likely to be short term for the duration of the active site? What are the effects of shading and changes in soil microbial activity and microclimates under the panels? Armstrong et al (2016) is useful background: https://iopscience.iop.org/article/10.1088/1748-9326/11/7/074016. What effect does

'rilling' have on soil loss / erosion, accelerated run-off and in creating differential areas of soil wetness? A discussion of short term changes in soil properties vs long term physical limitations (as in ALC) would be useful. A summary of claimed benefits to soil from previous cases would be very helpful.

3. Review and summarise to what extent evidence supports solar PV sites are physically reversible to agriculture in the BMV and non BMV context. What are the main issues and what evidence is there to support this? What factors influence reversibility (e.g. soil handling conditions, monitoring, soil types & climate).
4. Discuss the parallels between mineral site restoration and solar PV site restoration? Are the two comparable or do significant differences exist?
5. Discuss the parallels with golf course or similar type developments or activities and their reversibility. Are these comparable or do significant differences exist? IN Wales, Technical Advice Note 6 "TAN 6" (para 6.2.2) - Planning for Sustainable Rural Communities says, *"once agricultural land is developed, even for 'soft' uses such as golf courses, its return to agriculture as best and most versatile agricultural land is seldom practicable".*
6. Discuss to what extent soil handling conditions, as part of the planning process, can mitigate or remove any threats to soil and land. Can BMV sites realistically be restored to BMV and what factors influence this? Again, differences between sites will be useful to discuss.

Work Package 4: Summary of key issues and recommendations for future work

Based on the above work packages:

1 Summarise the key findings from this work. A non-technical executive summary is needed.

2 Identify evidence / knowledge / experience gaps.

3 Recommend what future work is needed to better understand the impacts of solar PV sites on soil and land.