Escola Superior de Tecnologia e Gestão de Bragança

Untapping The Full Potential Of Solar Farms In The UK: Different Approaches To Land Management

Ana Maria Rodrigues Esteves

Relatório de estágio apresentado à Escola Superior de Tecnologia e Gestão de Bragança para obtenção do Grau de Mestre em Energias Renováveis e Eficiência Energética

Orientada pelo Prof. Dr. Orlando Soares

Este relatório de estágio inclui as críticas e sugestões feitas pelo Júri.

Bragança, Novembro de 2016

Abstract

The United Kingdom (UK) Government's strategic to meet the target of 15 per cent renewable of primary energy from final consumption by 2020, and help the delivery of carbon reductions, have introduced support mechanism. These support mechanism includes: Feed-in Tariffs (FiT), Renewable Obligation (RO) and Contracts for difference (CfD). The increase installation of utility-scale photovoltaic (PV) plants and the competition between food and energy brought an important topic for discussion the full potential of solar farms. Once after installation of the infrastructure around 70% of ground remains available, so this project proposes and analyses the different approaches to land management. The land management suggestions are agricultural use (crops, grazing and beekeeping) and biodiversity use (hedgerows, security fencing, field margins, grassland (wildflowers meadow) and nest boxes). A number of impacts during the solar development cycle (development phase, construction phase and operational and maintenance phase (O&M) and the environmental, land-use, biodiversity and socio–economic impacts, are studied and analysed for each of the possible options for ground. The suitable use is selected by developers, so the impacts of the different land management studies on are devices to help them in this decision. Therefore any land management option, however expensive is their implementation or maintenance is preferable than just cutting the vegetation, where there is no land management use.

Key-words: land management, solar PV, development, construction, operation and maintenance, agriculture, biodiversity, impacts.

Resumo

Até 2020 cerca de 15% da energia primária consumida no Reino Unido terá de ser produzida a partir de fontes renováveis. Para ajudar a atingir essa meta, e de forma a reduzir as emissões de carbono, foram introduzidos mecanismos de suporte. Estes mecanismos incluem: FIT, RO e CFD. O aumento das instalações fotovoltaicas de grande escala e a competição entre alimentos e energias trouxeram um importante tópico de discussão: o potencial dos parques solares. Uma vez que após a instalação da estrutura cerca de 70% do terreno permanece disponível, este relatório de estágio propõe-se a analisar as diferentes abordagens da ocupação do solo. As diferentes ocupações do solo sugeridas são o uso agrícola (colheitas, pastoreio e apicultura) e para o uso da biodiversidade (sebes, cercas de segurança, margens de campo, pastagens (prado de flores silvestres) e ninhos para pássaros e morcegos). Sendo estudados e analisados uma série de impactos durante o processo de desenvolvimento de uma planta PV (fase de desenvolvimento, EPC, O&M) e os impactos: ambientais, estrutura do solo, biodiversidade e socioeconómicos, relativamente a cada uma das opções possíveis de ocupação de solo. Acabe aos planeadores a decisão da melhor ocupação do solo, sendo os impactos dispositivos que irão ajudar nessa decisão. Conclui-se que a opção de gestão da ocupação do solo, por mais dispendiosa que seja a sua implementação ou manutenção, é preferível do que unicamente a remoção da vegetação onde não há uso do solo.

Palavras-chave: ocupação do solo, solar PV, agricultura, desenvolvimento, construção, operação e manutenção, biodiversidade, impactos.

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List of Abbreviations and Acronyms

A

AC
  alternating current, 21

B

BMV
  Best and Most Versatile, 14

C

CfD
  Contracts for difference, ii

CO_2
  carbon dioxide, 2

D

DC
  direct current, 21

DECC
  Department of Energy and Climate Change, 12

DNO
  Distribution Network Operator, 14

E

EIA
  Environmental Impact Assessment, 19

ETS
  Emissions Trading Scheme, 8

EU
  European Union, 5

F

FiT
  Feed-in Tariffs, ii

H

H&S
  Health & safety, 43

ha
  hectares, 15

J

JB
  Junction Boxes, 21

K

kW
  kilowatt, 4

kWh/m^2
  kilowatt-hours per square metre (, 3

L

LPA
  Local Planning Authority, 16

M

MV
  medium voltage, 20

MW
  megawatt, 10

N

NPPF
  National Planning Policy Framework, 31

O

O&M
  operational and maintenance, ii

OFGEM
  the Office of Gas and Electricity Markets, 9

P

PV
  photovoltaic, 2

R

RO
  Renewable Obligation, ii

ROCs
  Renewable Obligation certificates, 9

ROI
  return on investment, 15

S

SPV
  Special Purpose Vehicle, 16

U

UK
United Kingdom, ii

W

WPD
West Power Distribution, 14

Chapter 1 –Introduction

The UK government has committed to supplying 15% of primary energy supply from renewable sources by 2020, which means 30% of the electricity generation would need to be from renewable sources (EC Renewable Energy, 2016). To meet this target, the government implemented over the years a number of support mechanisms, including: Feed-in Tariffs (FiT), Renewable Obligation and Contracts for difference (CfD) (EC Renewable energy, 2016). As a consequence of the supporting mechanisms, the generation capacity from renewable sources is growing rapidly, especially in solar energy systems, mainly the large centralized installations (R.R. Hernandez et al., 2013)

The solar energy has huge positive aspects, such as: reduction of greenhouse gases (i.e. carbon dioxide (CO_2)); stabilization of degraded land; increased energy independence; job opportunities; increasing of rural electrification; and also can improve the quality of life ((R.R. Hernandez et al., 2013). However, the rapid increase on deployment of solar PV accentuates the importance of understanding its environmental and social impacts.

The installation of utility-scale photovoltaic (PV) plants requires a substantial amount of land take. Therefore, the use and management of the land within the solar PV plants becomes a very important topic of discussion. After installation of the solar PV panels around 70% (infrastructure typically covers only 30% of a site) of ground remains available for additional land uses such as agricultural use (i.e. crops and grazing) and biodiversity (Scurlock, 2013)

According to Fuller, R.M (1986) over the last 50 years around 60% of British wildlife has declined. Since the 1930's that have been reduced 97% the availability of habitats suitable for wildlife (i.e. Bumblebees) (Fuller, R.M.; 1986). The change in land-use and agricultural intensification (i.e. increased use of fertilizer, intensive grazing) can be appointed as the responsible to these declines (Carvell, 2002).

It is important decide the type of land management to be implemented during the planning phase of a project, to reduce costs on construction and operation and maintenance (O&M) over the many years of a solar project's life (25 years) and prevent damages that can be caused by underneath vegetation. Also a suitable land management can lead to significant benefits for wildlife. There are good practice examples of land management, such as agriculture (crops, grazing and beekeeping) and biodiversity (wildflower meadows), that solar companies and planners can implement on solar sites to boost the biodiversity and the productivity of the land (Parker, 2014).

1.1.Objectives

Based on reviewed published scientific literature and discussions with professionals, this dissertation proposes and discusses the land management options for solar PV sites in the UK, and this way untapping the full potential of solar farms. Being presented different approaches to land management, where are focused the agricultural use (different crops, grazing and beekeeping) and biodiversity use. These options were described and their impacts were analysed during the solar development cycle (development phase, EPC phase and O&M phase) and in terms of environment, land-use, biodiversity and socio–economic impacts. In the end of this study is presented the results that can be followed by developers and planners to deciding the suitable land management option in agreement with i.e. the location of the solar PV and the financial plan.

1.2. Description of land features in the UK

1.2.1. Fauna and Flora in UK

The land in the UK has a variety of natural vegetation, due to its mild climate and varied soils. The most common trees in England are Oak, elm, ash and beech. Pine and birch are most common in Scotland. However most of the lowland outside the industrial centres is farmland, with a diversity of semi natural vegetation of grasses and flowering plants. Fens and marshes, cliffs, chalk downs and mountain slopes are covered with wild vegetation such as heather, grasses, gorse, and bracken. The common smaller mammals are foxes, hares, hedgehogs, rabbits, weasels, stoats, shrews, rats, and mice. There are few reptiles and amphibians. Approximately 230 species of birds reside in the UK, and another 200 are migratory. The number of birds is declining, except the bird pheasant, partridge and red grouse, which are protected. There are more than 21,000 species of insects (National Encylopedia, 2016).

1.2.2. Irradiation in the UK

The current average UK annual irradiation is in the range of 750–1,100 kilowatt-hours per square metre (kWh/m^2) (figure 1). This solar irradiance is the total of solar energy reaching the horizontal surface, i.e., the sum of direct and diffuse radiation (radiation that has been spread by the atmosphere or reflected from the ground) (European Union Maps, 2011).

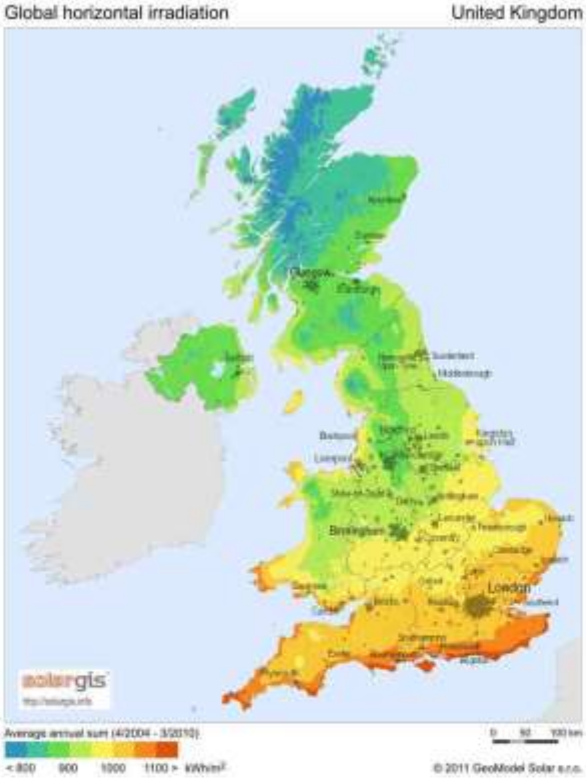

Figure 1– Global Horizontal Irradiation in UK (European Union Maps, 2011)

The current solar energy resource in the UK offers a huge untapped potential, especially in the South of England and Wales (see figure 1). Where the amount of electricity that can be generated by an optimally positioned 1 kilowatt (kW) rated PV solar panel (i.e. in a yellow area Leeds, a 1kW solar panel should produce 825 kW hour (units) of electricity in a typical year while in a brick red area Plymouth would produce around 950 kW hour) (European Union Maps, 2011).

1.3.3. Agricultural area in UK

In 2016, the total utilised agricultural area in England is 9.0 million hectares. These hectares are distributed by arable and horticultural crops, uncropped arable land, land used for outdoor pigs, temporary and permanent grassland and common rough grazing. Where, the land available for cropping remained almost unchanged at 4.8 million hectares, 54% (included cereal, oilseeds, potatoes, other arable crops, horticultural crops, uncropped arable land and temporary grassland figure 2) (DEFRA, 2016).

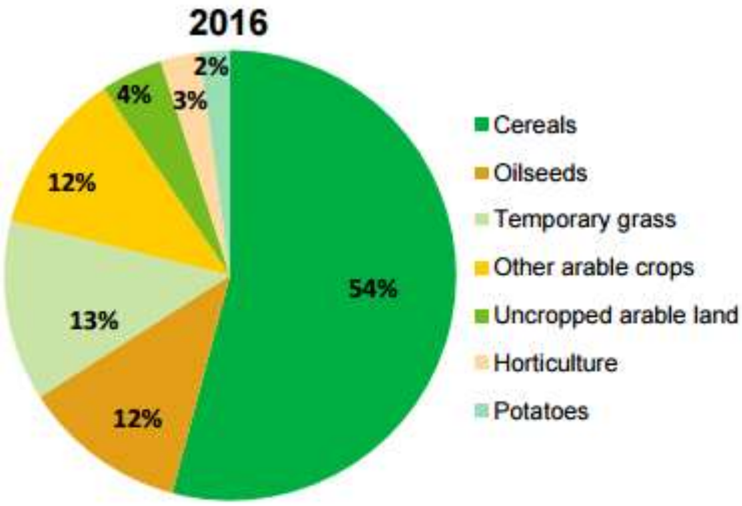

Figure 2 -Total croppable area at 1 June 2016(DEFRA, 2016)

1.3.Scope of the project

The introductory chapter, chapter 1, is an introductory chapter. There are also present the main objectives as the structure of this project. A brief description of land features in the UK, such as fauna and flora; irradiation; and agricultural area are also provided.

The chapter 2 summarises the Legislative Framework for Renewable Energy, providing a description of the 2020 European Union's (EU) Renewable energy directive target achievement, and the proposed policies for 2030 and 2050 to achieve the targets. It also presents the governmental programmes to increase the proportion of the electricity supplied from renewable sources and low-carbon electricity generation technologies. The first sections present and discuss the targets expected on future renewable energy for 2020, 2030 and 2050, with the policies and support to achieve those targets; the last sections examine the deployment of solar PV in the UK and its progress against the relevant targets.

The chapter 3 provides an overview of the project development process, identifying and describing the stages involved. The process starts by identifying a suitable site and assessing its feasibility for development, progressing through permitting, licences and authorizations.

The chapter 4 analyses the construction process, providing a description of the activities involved. This process can be divided into two phases, with the first phase being the pre-construction phase, where preliminary works must be done to minimize environmental impacts resulting from construction; and the second phase being the construction of the solar PV. The management of the construction activities should be in accordance with construction management best practice, so in the end of this chapter, a number of good practices are proposed.

Chapter 5 presents the O&M phase, where the main objective is ensure that the PV plant works continuously and reliably, thus maximizing the performance and economical returns. This chapter describes the main O&M activities, which can be separated into scheduled/preventive maintenance and unscheduled maintenance. A brief description of asset management is also provided.

Chapter 6 describes the land management options that developers can implement on the solar PV sites. This chapter is divided in two parts: agricultural (crops, grazing and beekeeping) and biodiversity (i.e. low grow grass).The crop subsection explains the interaction between shading and crops, radiation and water availability for the crops assessed (lettuce, cucumber, beans and tomato). A separate subsection also looks into crop management, describing cropping cycle, location on solar PV sites and management (i.e. spacing between rows and plants and harvest's date), to evaluate the viability of each crop on solar PV sites, this subsection also evaluates and analyses the water needs for each crop. The grazing subsection describes the grazing management, followed by good practice. The beekeeping subsection presents and describes the maintenance and management activities, i.e. hive cleaning, period frames replacement. The last part describes and studies the biodiversity options that are determined by the site characteristics in terms of environment, location, pre-existent biodiversity and land use.

Chapter 7 describes and analyses the impact of each land management option in terms of feasibility through design features (development), construction cost, and O&M cost. Then is compared the impact of the vegetation control without land management specific (mowing). The last subdivision describes the impact of each land use on environment (soil, water and air recourses, biodiversity (wildlife and habitats), land-use and socio-economic, compared with a land use prior to its construction (wheat crops).

The last chapter, conclusion, synthesizes the results of the study.

Chapter 2 - UK Legislative Framework for Renewable Energy

The UK government has signed up the EU Renewable Energy Directive 2009 (EU RED) and is implementing the 2008 Climate Change Act in order to meet a target to supply 15% of energy from renewables by 2020, divided between renewable electricity, heat and transport. This will require a large decarbonisation of the national electricity grid. In order for the UK to meet this target, the Government expect that 30% of electricity generation would need to be from renewable sources (Fitzpatrick, 2014).

2.1.Renewable energy targets for 2020

The EU's Renewable energy directive sets an obligatory target of 20% final energy consumption from renewable sources by 2020 in the EU. To achieve this, EU member states have committed to reaching their own national renewable targets. However, it is a requirement that at least 10% of their transport fuels come from renewable sources by 2020.

To meet their renewable targets all countries have defined their own strategy. This strategy includes: an individual renewable energy target for the electricity, heating and cooling and transport sectors; planned mix of different technologies; planned policy measures e.g. support from local, regional and national authorities; and planned use of cooperation mechanisms such as statistical transfer, joint projects and joint support schemes(EC Rewable Energy, 2016).

2.2.Renewable energy new target for 2030 and 2050

The European Commission has also projected targets for renewable energy in 2030, which include: at least 27% of energy consumption should come from renewable sources; a 40% cut in greenhouse gas emissions compared to1990 levels and at least 27% energy savings compared with *'business-as – usual scenario'*.

The proposed policies for 2030, that seek to meet these targets, are:

- Reformed EU Emissions Trading Scheme (ETS);
- New indicators for the competitiveness and security of the energy system such as price differences with major trading partners, diversification of supply, and interconnection capacity between EU countries; and
- The EU to have a more competitive, secure and sustainable energy system(EC Energy Strategy , 2016)

This new agreement between EU countries including EU-wide targets and policy objectives for the period between 2020 and 2030 will help plan possible scenarios for 2050, such as EU more competitive, secure and sustainable energy system and greenhouse gas reductions target. Then up to 75% of final energy consumption will come from renewable sources(EEA, 2016)

2.3. Policies and Support Mechanisms Overview

The governmental programme announced support mechanisms to create an increasing proportion of the electricity supplied from renewable sources and low-carbon electricity generation technologies (EC Rewable Energy, 2016).

These support mechanisms are FiT, RO and CfD.

2.3.1. Feed- in Tariffs

In April 2010, the FiT scheme was introduced to support small-scale solar PV, installations with generation capacity up to a maximum of 5MW of electricity.

The scheme is currently being reviewed; new rates for PV installations over 50 kW took effect from 1 August 2011 and for installations at all scales on April 2012. By the end of May 2011 nearly 38,000 solar PV installations in Great Britain were receiving support through the Feed-in Tariff (Fitzpatrick, 2014).

A new FiTscheme opened on 8 February 2016, with different tariff rates and rules, such as limits on the number of installations supported (Ofgem RO, 2016).

2.3.2. Renewable Obligation (RO)

Whilst smaller scale renewable electricity projects are mostly sustained by the FIT, large-scale projects have as their principal support the RO (Ofgem RO, 2016).

When it was first introduced in 2002 in the UK (Northern Ireland in 2005), each renewable energy technology received the same level of support for electricity generated, measured in Renewable Obligation certificates (ROCs) /MWh. ROC are certificates issued by the Office of Gas and Electricity Markets (OFGEM)to operators of accredited renewable generation stations. These operators can then sell the ROCs to electricity suppliers, who need to surrender them to meet their obligations. Since the RO was announced, it has been the main support for renewable energy in the UK. On 31 March 2017 the RO will be closed to all new generating capacity (Ofgem RO, 2016).

2.3.3. Contracts for difference (CfD)

After announcing the intention to close the RO for new generating capacity, the UK government has introduced the CfD, which is being managed by Low Carbon Contracts. Whilst a few projects have been awarded contracts in a past CfD auction, currently solar PV has been excluded from future rounds of CfDs (Fitzpatrick, 2014).

2.4.Tracking progress in the UK - Progress Report

The EU member states are obliged to report every two years on their progress towards meeting the 2020 renewable energy targets.

According to the National Grid, the UK will miss its EU 2020 targets of producing 15% of total energy from renewables, split between electricity, heat and transport. Whilst this target may not be complied with, the UK will surpass its 30% target by 2020, with approximately over a third (34%) of electricity from renewable sources. The National Grid believes that only 12% energy from renewable will be achieved by 2020, with the 15% target expected to be settled on 2029 (Prata, 2016).

2.4.1. Solar photovoltaic deployment in the UK

At end of July 2016, overall UK solar PV capacity was 10,799 megawatt (MW) with 892,817 installations (see table 1). This is an increase of 29% (2,423 MW) compared to July 2015.

Table 1 - UK Solar PV capacity and installations (GOV.UK, 2016)

Month of publication	Values	Feb-2016	Mar-2016	Apr-2016	May-2016	Jun-2016	Jul-2016
		Commissioning month					
Feb-2016	*Capacity (MW)*	9,213					
	Count	867,876					
Mar-2016	*Capacity (MW)*	9,323	9,519				
	Count	868,366	872,967				
Apr-2016	*Capacity (MW)*	9,446	9,778	9,790			
	Count	868,513	873,305	877,267			
May-2016	*Capacity (MW)*	9,554	10,153	10,166	10,265		
	Count	868,655	873,521	877,645	882,440		
Jun-2016	*Capacity (MW)*	9,646	10,387	10,400	10,450	10,478	
	Count	868,806	873,706	877,837	882,886	887,992	
Jul-2016	*Capacity (MW)*	9,763	10,647	10,671	10,721	10,783	10,799
	Count	868,960	873,892	878,026	883,075	888,480	892,817

July 2016 noticed16 MW worth of solar PV capacity being deployed throughout the month, with the main drivers (66% of capacity) being small scale 0 to ≤ 4 kW schemes in Great Britain and Northern Ireland, as per figure 3) (GOV.UK, 2016).

Within the last 12 months, the largest increase in capacity occurred in March 2016 (884 MW), just before the RO was closed for certain installations.

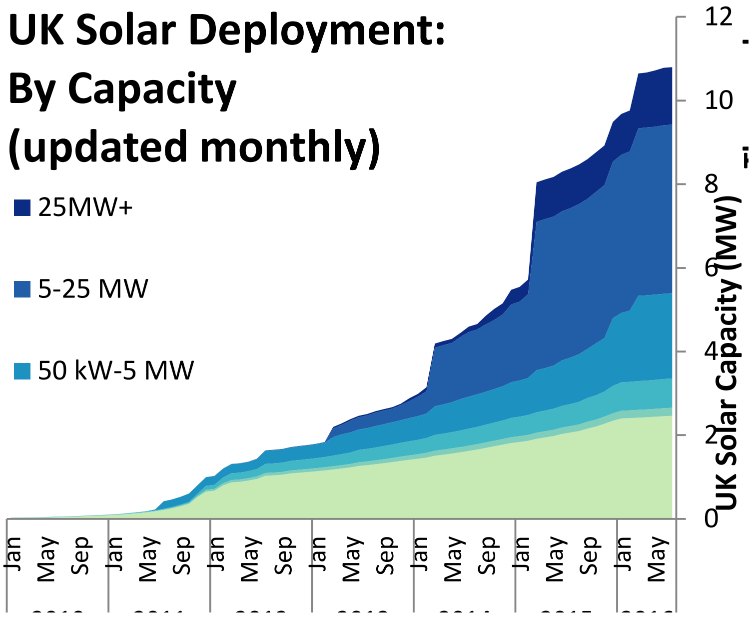

Figure 3 - UK Solar PV deployment by capacity (GOV.UK, 2016)

A solar Policy Analyst for UK Solar (sector group of the Renewable Energy Association dedicated to solar), Lauren Cook, explains that the cuts on solar PV subsidies are responsible for this decrease, i.e. the cuts to the feed-in tariffs, the closure of the RO for most installations and proposed tax policy change. Therefore it is essential that the government adjusts and eliminates these obstacles. Department of Energy and Climate Change (DECC) has recently been abolished and replaced by the Department for Business, Energy and Industrial Strategy and in the absence of an energy strategy it is not possible to predict what the future holds for the solar industry in the UK. The government declared that it will continue to support the solar industry but expects it to be sustainable in the long-term and this means that it needs to be driven by competition and innovation instead of receiving subsidies (Cuff, 2016).

Chapter 3 - Developing successful utility-scale solar Power: Development process

This section provides an overview of the project development process, involving various stages that are be identified and described below.

3.1. Feasibility - Preliminary site assessment

3.1.1. Site identification

The developer selects the suitable sites for the development of photovoltaic plants.

A suitable site should ideally meet certain criteria, such as:

i) Accessible grid connection (to minimise the costs associated with grid connection works, sites should be located as close as possible to the Point of Connection (POC) (overhead lines, underground cables, substations), and be located within the same land ownership as the site to be developed, thus avoiding the need for third party way leaves and associated fees). The Distribution Network Operator (DNO's) infrastructure is shown in maps issued by the DNOs (i.e. West Power Distribution (WPD), UK power Distribution). Some DNOs choose to highlight which areas of their infrastructure have generation constrains. In addition to this, periodic meetings with DNOs are encouraged to ascertain which areas of the network remain unconstrained (Kellemberg, 2015).

ii) No serious environmental or social concerns, including:

1. Landscape designations - avoid areas with important designations such as: World Heritage Sites, National Parks, Areas of Outstanding Natural Beauty, Sites of Special Scientific Interest and Green Belt;
2. Land use - sites should be selected within areas where the soil quality is poorer for agricultural purposes. Sites within land classification grade 1, 2 and 3A are not encouraged as these are considered Best and Most Versatile (BMV) land; and
3. Flood risk (areas within classification Flood Risk zone 2 and zone 3 should be avoided. However, the feasibility of these sites will depend on topology of the site and historical flood levels. A detailed flood risk assessment would be required to determine feasibility on zone 2 and 3 sites.

iii) Some topographical features to consider are:

1. Access
2. Slope - avoid sites with north facing slope above 3%, because these sites will require more area available for the same installed capacity.
3. Shading on the PV panels
4. Size -minimum 10 hectares (ha) of available area required for a 5MW PV plant-
5. Visibility - sites that are highly exposed to receptors are likely to have a higher planning risk and lower community support. The search should be focused on well screened sites, normally surrounded by vegetation (hedges or trees) (Kellemberg, 2015).

3.1.2. Site assessment

Following the identification of a suitable site, a preliminary assessment should be undertaken. This assessment should include:

- planning assessment – compliance with planning policy
- grid connection assessment – determine expected POC based on location of infrastructure and existing constrains
- technical assessment – estimate installed capacity (MW), yield
- Financial assessment – a preliminary assessment of costs and benefits can be made, including return on investment (ROI). A preliminary financial model is often developed at this stage (Kellemberg, 2015).

3.2. Exclusivity

Once a site is considered feasible, the developer agrees the main commercial terms with the landowner and an exclusivity agreement is signed between the parties. It is not uncommon to also sign a heads of terms agreement which sets out the main terms for the Option for Lease and Lease. The exclusivity agreement normally lasts 6 to 12 months and provides the developer with the security required to invest funds in the early stage development activities, until an Option for Lease is completed (Kellemberg, 2015).

3.3. Application for grid connection

The developer will submit an application for grid connection to the relevant DNO, who normally takes 65 working days to issue a connection offer. Should the connection offer be feasible, i.e., provide the required capacity at an acceptable cost, the developer will accept the grid connection offer and make the relevant payment to the DNO (Kellemberg, 2015).

3.4. Property – Option for Lease and Lease

Once a grid connection offer is issued and the initial financial and technical assumptions validated, the developer shall start negotiations for the Option for Lease. This document will enable the developer to hold an option to require a lease (which is normally attached to the Option for Lease) on a given site for a number of months, typically 24 months. A lease agreement typically lasts for 25 years. This document includes the commercial terms and rights and obligations of the parties (Kellemberg, 2015).

3.5. SPV

To facilitate the development and operation of the PV Plant a project company or a Special Purpose Vehicle (SPV) should be created. This company will retain all the rights and permits required for the PV Plant to operate including lease agreement and connection agreement. The incorporation of the SPV should be done at an early stage to minimize legal and administrative work associated with assignments and transfers of contracts and permits (Kellemberg, 2015).

3.6. Planning

Once the project is confirmed as viable following the grid connection offer, the developer shall prepare and submit, to the relevant Local Planning Authority (LPA), a planning application for the construction and operation of the PV Plant.

The developer shall hold where possible pre-submission discussions with the LPA and submit a screening and scoping opinion request. This will allow the developer to understand, which are the key issues to be addressed in the planning application and documents required.

The developer shall also seek the opinion of the local communities and other stakeholders through public consultation events.

Following completion of the relevant assessments and community engagement the developer shall submit the planning application, which will normally be determined within a period of 13-16 weeks after its validated (Kellemberg, 2015).

Chapter 4 - Construction phase

Construction of large-scale solar PV should be outside of the sensitive times for protected species that have been identified through a phase 1 – Habitat Survey or as part of an Environmental Impact Assessment (EIA). Also activities that will result in disturbance or removal of habitats should be avoided during the main periods for protected species, e.g. the bird breeding season, between 1st Mach and 31st July. It is acknowledged that an organized and tidy site will help to avoid negative impacts on wildlife, this includes practices such as covering excavation; keeping tools locked up; reducing soil compaction by minimising vehicle movements and using low ground pressure vehicles, especially during wet weather. The management of the construction phase of a solar PV project should be in accordance with construction management best practice. The aim should be to construct the project to the required level of quality within the time and cost constraints (Parker, 2014).

4.1. Pre-construction phase

Before the construction start, there are preliminary works that need to be done to avoid disturbing the balance on the natural environmental. These include: cleaning the area for the construction compound and removing any physical obstacle that could prevent the correct erection of the infrastructure; preparing the perimeter for any temporary fencing inside the site to prevent damages on existing tree roots or any other element with significant importance; and installation of provisional track ways to allow the access with machinery to the places where significant loads will be moved. In accordance with the law it is mandatory to assure the proper health and safety conditions for the workers; for this purpose temporary health and safety facilities that include a locker and changing room, a canteen and toilets equipped with hot water need to be installed on site to support the workforce (Stud Farm , 2015).

4.2. Construction phase works

The construction period of a solar farm should take approximately five months and the main activities are described in the following subsections.

4.2.1. Hedgerows and erection of fence and gate

To secure the site, providing a natural security perimeter and ensure protection of the existing hedgerows and trees, prior to any construction activity the final fence (figure 7) and the access gates should be installed on the boundaries. This fence will be designed to reduce any visual impact

Fencing around the perimeter of each panel area should be installed and such a fence can include badger / fox / small mammal flaps at regular intervals to allow smaller animals into the protected areas. Usually smaller animals and reptiles need to be able to move without any restriction after the construction has been completed (Stud Farm , 2015).

4.2.2. Preparation of onsite tracks and laydown areas

The main purpose of the tracks that are needed on a solar farm is to allow the transport and installation of the major medium voltage equipment (inverters, transformers and switchgears).Although there are other elements that have significant dimensions (control house, client substation and DNO Substation (Figure 4)), this equipment usually located near the main road that gives access to the site avoiding the need of a dedicated route. Either way, it is necessary to allow access not only during construction phase but also for the operation and maintenance period.

For construction (on a pre-construction phase as indicated on subsection 2.1), and to avoid the dependence of the weather conditions usually temporary aluminium roads are installed in the place where the final track will be built. This solution does not need any type of earth movements as aluminium plates are laid on the soil directly and these provide a safe access to the areas where the medium voltage (MV) equipment will be installed or if necessary to allow the access to the site. Normally, there also have an unloading area to receive deliveries and serve as staging area during construction. These provisional track ways are easily removed after the works are finished, allowing consequently the beginning of the works for the final road. The final road that should remain during the life time of the project, is usually executed by removing a layer of the topsoil, then a permeable geotextile layer is used to separate the natural soil from aggregate stone that needs to be installed, providing a permeable road adapted forbearing the vehicles used for moving components when needed (Stud Farm , 2015).

4.2.3. Installation of inverters, transformers, control room and client substation

The electricity generated by the PV panels will be in the form of direct current (DC), so the inverters (centralized inverters are each co-located with transformers, which will be positioned strategically throughout the site) will convert this variable DC into alternating current (AC) suitable for supplying the electrical grid. This electricity generated AC will be forwarded by transformers to the client substation (Figure 4.), then the generated power will be exported to the DNO distribution (Stud Farm , 2015)

Figure 4 – Inverters, transformer, switchgears, client substation, DNO. Six Hills Solar Farm (Martifer Solar UK)

4.2.4. Installation of frames and panel, Cable laying

The PV Panels are fixed into a metallic structure (or frame) that is specifically designed in accordance with the panel's manufacturer indications. The legs of the panel frames should be piled directly into the ground, and the depth of the piles will depend on the ground conditions, however, the normal depth is around 1-2 meters. Panels within rows will be connected by cabling running along the structure, leading into Junction Boxes (JB) (boards that are spread on the PV Plant to collect the cables that run from the PV arrays, also called strings). The rows of modules will be kept at a fixed "tilt angle" (angle of the PV modules from the horizontal panel), to maximise the system of energy collection. This angle should be facing a fixed sloping angle orientated to the South, approximately 30-40 degrees from the horizontal. The PV arrays would then be connected together from the JB by DC cables buried in ca. 600- 1000mm deep trenches. Beyond the inverters AC cables will be required and these will be placed in trenches approximately 1.0-1.2m deep. The network of cable trenching would, where possible, be designed and implemented in a manner which minimises the distance of trenching required. The trenches would be excavated and backfilled by a tracked excavator (Stud Farm , 2015).

4.2.5. Testing and commissioning of the panels and grid connection

The testing and commissioning of the photovoltaic plant should be undertaken by the general contractor and an electrical engineer together with the DNO supervision (Stud Farm , 2015)

4.2.6. Demobilisation from site and reinstatement works – Site landscaping

Once the construction phase has been completed the site will be landscaped. The groundcover will be re-established to increase the biodiversity. Therefore the site will be prepared to allow the land option that has been designed, such as agriculture use (e.g. grazing, crops, beekeeping) or biodiversity (Stud Farm , 2015).

4.2.7. Decommissioning phase

The project has an operational lifespan of twenty five years. Once this time has been reached, the project enters its decommissioning phase, and then all equipment would be dismantled and removed from site. All components of the panels should be recycled. The perimeter security fence should also be removed. Therefore after the removal of the solar farm's structures and infrastructures facilities (i.e. panels, transformers control buildings and substations) the site should be returned to its previous agricultural use. Also waste materials should be transported to an appropriate and licenced place (Stud Farm, 2015).

4.3. Good practice in construction and installation

During the construction and installation of the solar farm it is important to follow good practice. The general measures recommended are:

- Existing hedgerows and mature trees would be retained on all site boundaries. A root protection zone should be created along the entire hedge boundary to protect the species-rich hedgerows from compaction and root damage during the construction phase. This measure will also protect the existing field margins.
- Existing semi-natural grassland would be retained and protected through the construction phase.
- Construction and any associated vegetation removal should be undertaken outside of the bird breeding season (March to August inclusive) in order to avoid impacts on

nesting birds and to ensure compliance with the provisions of the Birds Directive and the Wildlife and Countryside Act 1981. However if these works cannot be avoided during this season, suitable nesting habitat should be hand-searched by an experienced ecologist prior to works commencing.

- Native British plants should be used ;
- The use of herbicides should be reduced to guarantee the greatest biodiversity onsite. If weeds are becoming a problem ecologically sensitive control procedures should be taken such as topping, hand pulling or weed wiping using e.g. a sensitive herbicide. Any use of pesticides and fertilizers on site should be avoided or used in reduced quantities especially if the ground will be used for sheep grazing and only organic fertilizers should be used.
- When a wild flower meadow is to be established the use of any fertilizer is to be avoided and also on tussocky field margin areas (Southill Charlbury, 2015).

Chapter 5 - Operations and maintenance (O&M) and asset management

After construction and commissioning, the solar PV site will move to the O&M phase. The main objection of O&M is to ensure the plant operates continuously and reliably, thus maximizing the performance and economical returns.
When compared to other power generations technologies, solar PV power plants have low maintenance and services requirements. However the proper maintenance of a PV plant is essential to maximise both energy yield and the plant's useful life (Miller, A.; Lumby, B., 2015).

A well-maintained solar installation can actually perform 10 to 30% better than one that is not. Additionally, without proper O&M, system components could be void of all warranties (Zipp, 2013). To ensure the construction contractor is liable during the warranty period, an O&M contract is agreed with the project company during the warranty period. Therefore the O&M contractor is responsible for all aspects of O&M, including any works performed by subcontractors that may be engaged to deliver specialist services, such as inverter, servicing, ground-keeping, security or module cleaning.

Maintenance can be separated in scheduled/preventive maintenance and unscheduled maintenance.

5.1. Preventative Maintenance

Preventive Maintenance is planned in advance and aims to prevent faults from occurring, as well as to keep the plant operating at its optimum level. Preventive maintenance activities typically include:

5.1.1. Module Cleaning

This is simple but important work that can make a substantial difference in terms of energy performance.

The frequency of cleaning will depend on local site conditions and the time of year, such as site and surrounding area ground covering (dusty and arid sites will result in more soiling) and local rainfall patterns (Zipp, 2013). However, clean modules operate up to 30% more efficiently thus it is very important to create a regular and effective cleaning routine (Greenheath, 2016).

5.1.1.1.Cleaning kits

One of the methods of cleaning includes the use of cleaning kits that comprise of biodegradable soap, a wiper, and a small brush or brush with a longer handle. It can be used with basic water or a soft brush to remove any grime or dirt that has built up on the panels but it is essential that a soft rag or biodegradable soap is used (Greenheath, 2016).

5.1.1.2.Automated machinery

Another method of module cleaning is by using automated machinery (figure 5). This system uses pressurised sprays of water and a rotating brush head to wash solar panels. When compared with the manual methods this method uses less water and can be adapted for use on a wide variety of machines and also locations (Lightsource, 2016).

Figure 5– Module cleaning by automated machinery (source: (Lightsource, 2016))

5.1.2. Checking Module Connection Integrity

Connection between modules should be checked periodically in order to prevent harm to the system and people. A loose connection can be a cause of fire due to a DC arc electric that tends to not auto-extinguish (Miller, A.; Lumby, B., 2015).

5.1.3. Junction or string combiner box

The junction or string combiner box (figure 6) should be checked periodically for water ingress, dirt or dust accumulation and integrity of the connections within the boxes, to prevent corrosion or short circuit events that could affect the overall performance of the PV plant(Miller, A.; Lumby, B., 2015).

Figure 6 – Junction or string combiner box. Six Hills Solar Farm

5.1.1. Hot spots

The hot spots can be detected by thermography. This technology is able to identify malfunctions, weak and loose connections on photovoltaic cells within a solar array so they can be repaired or replaced quickly(Miller, A.; Lumby, B., 2015).

5.1.2. Inverter servicing

The inverter faults are the major cause of system downtime in PV power plants, so this part should be treated as a main part of the O&M strategy.

Normal preventive maintenance for an inverter should include: visual inspections, cleaning/replacement of cooling fan filters, removal of dust from electronic components, tightening of any loose connections and any additional analysis and diagnostics recommended by the manufacturers(Miller, A.; Lumby, B., 2015).

5.1.3. Structural integrity

All structures built for the solar PV power plant (module mounting assembly, cable conduits), should be inspected periodically to detected mechanical anomalies, erosion from water and signs of corrosion and presence of rodents.

5.1.3.1.<u>Pest control</u>

The presence of rodents (rats, mice, moles and squirrels) and their negative effect on cables' integrity is another issue in solar PV plants. The main cause of rodents presence on site, especially rats, are normally caused by containers used to deliver equipment on site during the construction phase, so the frequency of pest control routines should he intensified and preventive measures to control them applied and cables reinforced to ideally withstand the bites(Belfiore, 2013).

5.1.4. Other components

Other components of solar PV power plants should be inspected periodically, this includes: monitoring and security systems, auxiliary power supplies and communication systems (Miller, A.; Lumby, B., 2015).

5.1.5. Vegetation control

Vegetation control and ground keeping are important maintenance activities. Vegetation control will avoid shading on the modules and subsequent reduction in performance and ground keeping will decrease the risk of soiling on the modules from leaves, pollen and dust (Miller, A.; Lumby, B., 2015).

More details about the vegetation control methods such as grazing, crops, biodiversity, are provided on section land management.

5.2. Unscheduled maintenance

Unscheduled maintenance is executed in the event of operational failure of the PV plant. It is important to minimize the period between diagnostics and repair so the losses in the energy yield are kept to a minimum.
The typical issues that require unscheduled maintenance are:

- Inverter faults;
- Cable connections that have loosened;

- Cables damaged by rodents;
- Replacing blown fuses;
- Repairing lightning damage;
- Repairing equipment damaged by trespassers or during the module cleaning; and
- Rectifying Supervisory Control And Data Acquisition (SCADA) faults (Miller, A.; Lumby, B., 2015).

5.3. Asset Management

In addition to the O&M work, there is some management effort involved in managing the electricity export contracts and the finances associated with the site. All of this is undertaken by the solar farm operator. The O&M team has an understanding of the warranty terms from the suppliers so as to be informed of the likely nature of defects or problems that are covered under the warranty, and also the length of the warranty. Warranty requirements must be followed including documenting regularly conducted preventive maintenance to avoid the cancelling of the warranty (Miller, A.; Lumby, B., 2015).

Chapter 6 - Land management

One of the main advantages of Solar farms is that they generate clean energy, releasing us from a dependency on coal and gas, and that way reducing emissions of greenhouse gases into the atmosphere, including CO_2. This will help the fight against climate change, one of the biggest threats to the UK farming industry and wildlife. Therefore, while we generate clean energy, we will also have wider benefits arising from solar energy.

The solar farms comprise of PV modules which are fixed onto metal frames that are driven or screw piled into the ground, resulting in a minimal ground disturbance and requiring less that 1% of the land area. The remaining infrastructure usually occupies an area of less than 5% of the total area, and around 30% of the ground surface is covered by the projection of the modules or panels. This means that around 70% of the ground is still available for vegetation growth, and can support activities such as agriculture or wildlife for the lifetime of the solar scheme, normally 25 years (Scurlock, 2013).

The section below describes a number of good practice examples for the sitting and land use that the solar companies and planners can implement on the solar PV sites. For the purposes of this section, it is considered that the area of the site before construction was in arable use, mainly for wheat production (Monoculture).

6.1. Agriculture

Where possible it should be avoided to site solar farm development on best and most versatile land, selecting instead sites on lower graded fields. However, sometimes exceptions are possible, and when that happens there is a higher potential for successful implementation of agricultural activities (i.e. crops).

The National Planning Policy Framework (NPPF) provides a glossary of terms and defines the agricultural land classification. The NPPF requests that development in areas where the land classification is grade 1 (excellent), grade 2 (very good) or grade 3a (good) should be avoided. This so-called Best and Most Versatile land is land which is most flexible, productive and efficient in response to inputs and which can best deliver future crops for food and non-food uses such as biomass, fibres and pharmaceuticals (Natural England, 2012).

The area should be reverted to its original land use (this case arable land use) at the end of the project. Return of land use should be considered when planning habitat enhancements and care should be taken to ensure they do not alter the land use (Parker, 2014).

The land should be maintained in Good Agricultural and Environmental Condition, where soils, water, habitats and landscape features are properly maintained. Soil health is essential for the sustainability of farming in the longer-term. Therefore resting soils (uncultivated) for as long as possible is essential and would especially benefit soils that have been exhausted of their nutrients and compacted by farm machinery (Parker, 2014).

Most solar farm developers dynamically boost multi-purpose land use, with agricultural activity or agri-environmental measures that support biodiversity, yielding both economic and ecological benefits. The agriculture options for land use are outlined below.

6.1.1. Crops

The solar panels and crops compete for some resources such as radiation and water. However they have positive interactions, such as: the protection of the crops against high temperatures; or even increased water availability for the crops, when rainfall is concentrated and filtrated on a limited cropped area (Marrou, H.; Dufour, J.; Wery, J., 2013).

The height above the ground level of solar panels does not have an impact on the total quantity of radiation available at the soil level. However it has a huge impact in terms of heterogeneity of radiation. Thus the closer to the ground the panels are, the higher the heterogeneity is (Dupraz, C. et al., 2011).To achieve a profitable crop production, elevated solar infrastructure may be required, however further studies are necessary.

This study analyses lettuce-cucumber and runner bean-tomato crops, to be sown in spring and harvested in the summer/autumn.

*6.1.1.1.*Shade

The crops can achieve a high yield under the fluctuating shade provided by the solar panels, also the sitting below the panels could contribute to alleviate climatic stress and to save water requirement (Marrou, H.; Dufour, J.; Wery, J., 2013).

The specific conditions of shade created by solar PV on the production of vegetables are shown by studies which show that some vegetables such as lettuce has the ability to adapt to these conditions and compensate partially or totally to the reduction of sun availability by having a higher light harvesting capacity. This ability is based on the leaf morphology, where large leaves will work as solar collectors. (Marrou, H.; et al., 2012). However there are vegetables such as tomatoes that grow with full morning sun followed by afternoon shade and vegetables that grow in morning shade followed by afternoon sun, such as cucumber (Pleasant, 2012).

The vegetables that grow in vines and upward around objects such as beans or tomatoes are probably not suited to be grown under or between the modules, due to the characteristics of the crops and the potential shading effect on the PV modules. As recommended in the subsection below, this type of crop can be effectively a good option when supported on security fencing.

6.1.1.2.<u>Cropping Cycle and Seeding Management</u>

i) <u>Lettuce and Cucumbers</u>

Before planting the lettuce seeds, the soil should be loose (figure 7) , well drained and fertile (Marrou, H.; Dufour, J.; Wery, J., 2013).As the land use before construction was wheat that was grown constantly (monoculture), this would likely have required fertiliser before lettuce planting would take place.

Figure 7 – Preparation of the soil to receive the seeds. (Six Hills – Martifer Solar)

The cropping cycle for lettuce is April to May and for cucumber June to August, which means lettuces could be planted in March and harvested in May and cucumbers could be sown in the same place after lettuces have been harvested with soil deep tilling, in June and harvested in August (Marrou, H.; Dufour, J.; Wery, J., 2013).The lettuces can be planted in two rows, with spacing between rows 0.33meter (m) and distance between each lettuce 0.27m (facing North to South) (Marrou, H.; Dufour, J.; Wery, J., 2013), and cucumbers can be planted in single rows at a distance of 90cm separately, as recommended by Sue Sanderson, orientated in an East-West row (Sanderson, 2016). There should be space left between the rows of crops and also between the panels to avoid excessive overshadowing, and also to allow for suitable management.

ii) Runner Beans and Tomatoes

The beans that grow on vines, such as Runner Beans, and tomatoes (tall type) could be sown along the security fencing. This will provide a dual function, i.e. it will help to screen the security fencing and it will provide the farmer with bean and tomato crops. As the beans on vines and tomatoes need a support to climb up, the fence will fulfil this function and help them grow and create an ornamental feature. The fencing can also provide the plants with better ventilation, which reduces the risk of diseases especially in humid areas or seasons and the harvesting is easier (Naika, S. et al., 2005).

The suitable temperature range for successful tomato seed germination is between 18 Celsius (°C) / 64Fahrenheit (°F) and 22 (°C) / 72°F and it is practically impossible to reach these soil temperatures in the UK for germination early in the season, so it is recommended that seedlings are sown and grown indoors(Naika, S. et al., 2005). Then the tomato plant can be transplanted (plants with 15-25 centimetres (cm) tall and with 3-5 true leaves) to the solar PV site during an afternoon or on a cloudy day to reduce the transplanting shock.

Tomatoes can be planted in single rows between May to June, with spacing between plants 50 cm and soil depth of 15 to 20 cm to be harvest in July until October (Naika, S. et al., 2005).

In June a single bean seed can be sown at a depth of 5cm with distance of 30cm to be harvested in July until October, so the ground should be prepared in spring (fertile and well-drained)(Royal Horticultural Society , 2016). The Runner Beans and tomato plants should be loosely tied to the fence after planting to enable them to climb naturally.   Tomatoes can be grown in an intercropping system with Runner Beans. Two weeks before the tomatoes are harvested the beans can be planted in between the tomatoes. The fencing supporting the tomato will be used for the new crop. Further studies would be necessary to evaluate the viability of the beans and tomatoes on solar PV sites.

6.1.1.3. Irrigation technique

The irrigation technique that can be used in a solar farm and specific for these crops, and also solar PV features (i.e. electricity components) is drip irrigation (Marrou, H.; et al., 2012). Drip irrigation or trickle irrigation is the slowest method and involves dripping water onto the soil from a system of small emitters or drippers. This is the most suitable method for row crops and vine crops where one or more emitters can be provided for each plant (FAO , 2016).

It is suggested that water use efficiency in agricultural systems could be increased by selecting crop species and varieties with a rapid soil covering, which contributes to increased light capture and also to reduce soil evaporation, leaving more water plant transpiration and thereby for biomass production (Marrou, H.; Dufour, J.; Wery, J., 2013).

The lettuce should be irrigated every two days while cucumbers should be irrigated twice a week (H. Marrou at al., 2013). However that will depend on the weather conditions such as amount of rain, humidity and temperature. Shade will reduce transpiration needs, and possibly increase water efficiency (Dupraz, C. et al., 2011).

The tomatoes should be irrigated frequently especially during the flowering and fruit development period, but once again this will depend on the type of soil and climate conditions. Therefore in a suitable scenario and according with UK weather once a week should be sufficient (Naika, S. et al., 2005).

Throughout the growing season it would be necessary to water the beans regularly principally as they start to develop flowers.

6.1.2. Grazing

In planning applications for solar farms it is usual that the land between and underneath the rows of PV modules is kept in continued agricultural use, namely for the grazing of small livestock. Large farm animals (horses, cattle) are unsuitable due to their weight and strength, which would allow them to dislocate or damage the standard mounting systems, but sheep have already been successfully used to control the grassland whilst contributing to a dual-purpose land use (Scurlock, 2013) and is the option analysed in this study.

6.1.2.1.Grazing management

Establishing grassland on land previously used for wheat crops requires an appropriate preparation of the soil and establishment of the ground. Natural England suggests the following approach:

1. Prepare the site to reduce the weeds (can be ploughing in spring during wet period, and again in summer);
2. The seed application should be undertaken in late summer/early autumn (August/September), to ensure a good distribution and contact with the soil components (Stud Farm , 2015).

One of the measures that will use to maintain the productivity of grassland without the need of machines, is a seed mixture of 100% perennial ryegrass with a variety of species such as: timothy (highly palate), meadow fescue (tolerates wetter conditions), cocksfoot (deep rooting and suitable for dry soils), and alsike cover (tolerates lower pH and soil fertility) (HCCMPW, 2016) (see figure 8).

Figure 8 – Established grassland (Six Hills – Martifer Solar)

6.1.2.2.<u>Good practice in construction and installation</u>

The agricultural and biodiversity operations i.e. seeding of grass and wildflowers should be undertaken during the planting season. Contractors should avoid the use of heavy machinery that can compact the soil and also damage the land drainage. The soil (topsoil and subsoil) replacement in the correct position is import in order to avoid long-term unsightly impacts on the soil and vegetation structure. Following good practice during this phase will bring long-term benefits in terms of productivity and optimal grazing conditions (Scurlock, 2013).

6.1.3. Beekeeping

Beekeeping is the maintenance of bees in order to collect their honey and other products that the hive produces (i.e. pollen, royal jelly). Beekeeping encourages and supports the livehoods of bees preserving their habitats and biodiversity. Most UK bee species have declined significantly in recent years, because of changes in agricultural practices that have largely removed flowers from the landscape, leaving the bees with little to feed upon. They use the nectar from the flowers as a source to feed, as it is high in sugar. The pollen provides the protein and nutrients needed for growth and development. It is therefore unsurprising that the best habitats for bees are those that offer plenty of flowers to feed from during the entire active phase of the bee's lifecycle (from spring until late summer) (Bumblee Conservation Trust, 2016).

Beyond the hosting beehives and between and around the solar arrays species-rich grassland and wildflower meadows should be sown and maintained to provide nectar sources for honey-bees and other pollinators (more detail on wildflower meadows section) Providing both food and shelter makes the solar farms more welcoming to bees than the intensified agricultural monocultures (Bumblee Conservation Trust, 2016).

In this way the developments help to encourage the increase of biodiversity and subsequently the bees:

- Low human activity, except occasional maintenance visits (OMLET, 2016).
- A lifespan of 25 years, which is sufficient time for appropriate land management to yield real wildlife benefits

Spring is the start of the beekeeping season. If the weather is good and the bees are flying, the inside of the hive should be checked for around half an hour per hive. However, disturbance of the bees should be avoided. If their honey store is very low they must be fed. In April the flowers and nectar should start appearing. In spring the hive should be cleaned and any frames which are not in good condition should be replaced and any brace comb removed. Winter is the quietest season, but the hive should be inspected to make sure it is still secure (OMLET, 2016)

6.2. Biodiversity

According to the State of Nature Report the biodiversity is in decline in the UK and, 60% of the 3,146 species monitored have been recorded as declining over the past 50 years. That represents 1,064 farmland species, with intensification of agriculture being documented as the major cause.

Current studies reveal that good land management practices on solar farms have the potential to support wildlife and contribute to national biodiversity targets. There are various landscaping that will enhance biodiversity (see annex 3 –proposed solar farm) on solar farms and therefore the value of a site, including hedgerows, field margins, security fencing, wildflowers meadow and nest boxes. These elements are detailed in the following subsections (Parker, 2014).

6.2.1. Landscape elements

The biodiversity improvements can add value by creating different habitats, such as boundary features, grassland habitats and installation of nest boxes and bat and barn owl boxes. The selection of the best options will be determined by the site characteristics, because each site is unique in terms of environment, location, pre-existent biodiversity and land use.

The main options are presented below.

6.2.1.1.<u>Hedgerows</u>

Hedgerows or hedge is a column of vegetation and tree species, planted and preserved (figure 6) to mark the boundary of the site PV area. The hedgerows (figure 6) support an extensive diversity of wildlife, such as plants, invertebrates, birds, reptiles and mammals, providing food, shelter and habitats. Also they are essential for many species surviving, particularly in areas with insufficient woods. Here 30 species nest, and many of these (i.e. Bullfinches and turtle doves) prefer hedgerows over 4 meters tall, with a considerable number of trees.

However, species such as whitethroats, linnets and yellowhammers select shorter hedgerows (max 2-3 metres) with smaller trees. There are other species that prefer medium or tall with few trees (e.g. Dunnocks, lesser whitethroats and willow warblers). The grey partridge uses grass cover at the hedge bottom to nest. In order to support the wide variety of species and their needs, the developer should manage a range of hedge heights and tree densities.

The hedgerows should have a variety of shapes, sizes and woody species, which will provide species with flowers and berries at different times, therefore providing food over a longer period. Oaks can be a good option, because they support a wide variety of insects. Old trees often have holes in which blue tits, owls, kestrels and bats can nest (RSPB, 2016).

Figure 9– Hedgerows (Six Hills- Martifer Solar UK)

6.2.1.2.Field margins

The access route between the security fencing and the site boundary signifies an opportunity for establishing a habitat within the field margins, which is around 7-10 metres wide (figure 9). The perfect habitats for nesting bumblebees and birds in the summer time and invertebrate habitat in the winter time are uncropped tussocky grasses. They should be left uncut for about 2-3 years to allow them to develop (Parker, 2014).

6.2.1.3. Security fencing

Security fencing (figure 9) around the solar arrays can offer a perfect surface for growing climbers such as honeysuckle or clematis. This mixture will enhance the biodiversity, providing a nectar source to pollinators as well as acting as additional screening for the site. The security fencing must have a 20-30 cm gap between the base of the fence and the ground to allow small wildlife (e.g. badgers) to move freely across the site without disruptions to the site security. A native hedge could be planted outside the security fencing, which, in a few years, will add security value, visual protection and also increase the area's valuable habitat (Parker, 2014).

6.2.1.4.Grassland Habitat

Normally the grassland habitat is sown at the boundary of the site or under part or all of the solar arrays or a combination of both. After construction the ground should be covered rapidly with grassland. Varieties of grasslands appear to be the favoured option; however the combination between wildflower meadow and areas of tussocky uncropped grassland will increase the biodiversity (Parker, 2014).

i) Wild Flower Meadows

This land management option is a combination of wild flowers and fine grasses (figure 10). The variety of seed mix, which could be a wildflower meadow mix, should be selected in accordance with the soil type and conditions of the site. The specifications are: sun and shade tolerant, and also native to the UK. A successful wildflower meadow (several years after planting) requires a suitable management without fertilizers or herbicides, cutting or grazing at intervals throughout the year, to ensure the vegetation will not over-grow and shade the panel show ever should be avoided the cut and grazing through the summer to allow wild flowers to flower and provide nectar needed by bees and other insects. Therefore after summer and until December the vegetation can be controlled by grazing (Parker, 2014).

Figure 10 – Wildflower meadow (Parker, 2014).

ii) Nest Boxes

To encourage and increase access for roosting, nesting and/or hibernating birds, bats and small mammals, artificial structures such as nesting boxes and reptile hibernacula are normally agreed with the Council's ecologist. Where possible, bird and bat boxes should be erected within woodland areas directly neighbouring the site but this is only possible if the woodland is in the same land ownership. However, if it is not possible to accommodate the boxes within woodland the boxes should be erected on trees within the site itself (Parker, 2014).

Chapter 7- Impacts

7.1. Land Management Impacts

The following section describes the impact of the different land management options (agriculture, biodiversity) in terms of feasibility through design features (development), construction cost, and O&M cost. It also evaluates the option where the land management is limited to the cutting of vegetation to avoid overgrowth and shading on the panels. The identification and evaluation of these impacts has been supported in the reviewed published scientific literature and discussions with professionals. The table 2 and 3, reports the information described below and demonstrates the results.

7.1.1. Agriculture

7.1.1.1.Crops

i) Design, Construction cost, and O&M cost

In terms of project design a layout with irrigation systems should be included. The irrigation system should be compatible with the feasibility of the PV site. The distance between rows should be compatible with crops to avoid the shading effect, when they grow up.

During the construction phase it may be expensive to incorporate crops on a solar PV site in terms of establishing the ground cover. Also the cost of construction will increase due the cost of the water supply system (i.e. tubing, and emitters).

The O&M expenses would be high, because the time required in tending to the crops and the irrigation system used to ensure successful growth. There will be limitations in terms of the type of machines that would be allowed to clean the panels due to the space available, which would require more labour and also take more time. The human activity required to tending the crops will be high, especially during the seeding and harvest. So the site will be attended by people not qualified and this means an extra expense as Health & safety (H&S)training must be given, to avoid any damage or accident. A supervisor would also be required, therefore the financial impact on O&M is very high.

7.1.1.2.Grazing

i) Design, Construction cost, and O&M cost

In terms of design features the lowest edge of the panels will be no less than 700mm above ground level to allow for sheep grazing beneath them.

During the construction all cabling should be properly protected and the security system needs to be compatible with sheep, i.e. it must be able to distinguish between humans and sheep. This will also incur costs in terms of establishing the ground cover.

In terms of maintenance expense, as detailed in chapter 6, the expense for ground maintenance is low due to the seed mixture used. The solar project can get its biological lawn mowing system for free, avoiding the cost of machines, and also organic fertilizers (animal wastes) for the soil. All the cost associated with looking after the sheep (e.g. veterinary, sheep shearing) is paid for by owner of the sheep (third part benefits). In this case the H&S training is only for the shepherd, so the expense is very low.

7.1.1.3.Beekeeping

i) Design, Construction cost, and O&M cost

In terms of design features there is no additional design features needed. During the construction phase the soil should be seeded and maintained as species-rich grassland and wildflower meadows (the impacts on the establishment of wildflower meadows is more detailed below), so there will be no construction impact.

On O&M all the cost of taking care of the bees (i.e. visits to inspect the hives and to clean them) is an expense of the beekeeper. This land management has a low human activity, it only requires occasional maintenance. So the impact is low.

7.1.2. Biodiversity

7.1.2.1.Design, construction cost and O&M cost

In terms of design the layout of hedgerows should be considered, locating the hedgerow so that shading of the panels can be avoided, location of nest boxes, considering the suitable selection of security fences in accordance with growth of plants.

During the construction there will not be any impact.

On O&M the cost includes:

- *Hedgerows and wildflower meadow*

The surveys to ensure successful establishment of hedgerows and grassland (wildflower meadow) should be undertaken twice in the first year (ideally in May and September), annually from Years 2 to 5 and on a biennial basis thereafter, during the summer.

- *Security fencing*

The security fencing should be checked regularly to ensure they have not become blocked or fallen into disrepair.

- *Nest Boxes*

Monitoring visits should be undertaken by a licensed ecologist, throughout the lifetime of the project to monitor use of, and to maintain, the boxes. The boxes should be repaired or replaced as necessary.

The vegetation beneath the solar installation, with correct height and without growth above the panels (to avoid shading them) would prevent the accumulation of dust on the panels. This reduces the cost for maintenance.

7.1.3. Mowing

7.1.3.1. <u>Design, Construction cost, and O&M cost</u>

The design does not need any specific requirements.

During the construction there will be no impact.

On O&M the vegetation and pollen resultant from the cut can fix itself to modules, creating a shading effect and potentially a hot spot and affect the productivity. Following the mowing it is recommended that the panels are cleaned, which results in high maintenance cost (cost in terms of fuel, machinery, labour).

7.2. Environment impacts, land-use impacts and socio-economic impacts

This section describes the impacts of the land use adopted including: environment impacts (soil, water, air resources); biodiversity impact; land use impact and socio economic impact. In a hypothetic scenario it is assumed that the land use prior to the construction of the solar farm was arable land (wheat crops). Table 3 summarises the information described below and demonstrates the results.

7.2.1. Environment impacts

7.2.1.1. ***<u>Soil</u>***

Erosion control involves the creation of some sort of physical barrier, such as vegetation or rock, to absorb some of the energy of the wind or water that is causing the erosion. Vegetation establishment is now recognised as being a cost-effective and sustainable erosion-control technique (Florest Research, 2016).

i) <u>Crops</u>

Before planting crops the ground should be prepared, as described in chapter 6. This will require the use of machinery to prepare the ground to receive the crops. During the seeding/planting and the harvest period there will be disturbance by humans and equipment, which can cause some soil compaction. The crops i.e. beans are nitrogen fixing plants, as the nitrogen is vital for plant growth therefore the use of these crops will avoid the use of chemical fertilisers. Should more frequent panel cleaning be necessary due to the agriculture activity, this means more machinery and human activity and more compaction of the soil is likely. However, as the original soil was arable land, the crops would have a medium impact on soil.

ii) Grazing

Sheep grazing has the greatest potential to cause soil erosion, principally in areas with lot of sheep movement, so good grazing management techniques are crucial (described in chapter 6). Healthy and actively growing pasture plants such as available from the seed mixture will cover the soil and protect it from the erosive forces of wind and rain. In addition, the roots hold soil particles and minimize the effects of erosion.

It is likely that there will be compaction of soil during the grassland establishment due to the weight of machines used. However, this is temporary because in following years only sheep will be grazing the site and there will be some occasions when cleaning with machinery is needed. The sheep waste is the main organic fertilizer which means less chemical input into the soil. The impact on soil is low.

iii) Beekeeping

The vegetation covering the ground has the potential to control erosion (stabilising the soil material), reducing soil loss (including organic matter and nutrients). There will be occasional disturbance by humans and equipment due to the mowing and cleaning of panels. There is also low human activity required to supervise the hives. This means there will be no impact on soil when compared with previous land use.

iv) Biodiversity

There will be some compaction of soil during and the first year of the grassland establishment due to the equipment used, and during the following years little human activity for site maintenance will be needed. As mentioned above the vegetation covering the ground has the potential to control erosion and reducing soil loss. The boundary features (hedgerows and field margins) will work as barriers against the wind reducing soil erosion. So there will be no impact on soil.

v) Mowing

The major effect of mowing is compaction of soil, due to the heavy machines used and the high frequency. There will also be an increase in movement of machinery and human activity due to the cleaning requirement. Therefore the impact on soil is very high.

*7.2.1.2.**Water resouce***

Water is an important and natural resource, and also one of most vulnerable parts of environment and the provision of high quality water (i.e. water in our rivers, lakes and estuaries) is essential for health and survival. Good quality water enhances biodiversity and helps reduce the costs (expenses of treating water) and environmental impacts (Florest Research, 2016)

The selection of suitable land management practices should include the use of stress-tolerant species (with reference to climate and soil quality) with a naturally high production yield, which can provide a quick and efficient ground cover. This selection could combine the addition of soil amendments, the seeding of a grass/legume mixture and the planting of trees. However, this will depend on the specific site conditions (Florest Research, 2016).

i) Crops

A well-planned cover rotation (mainly during the summer growing season) reduces rainfall runoff, water infiltration rate, and also reduces the use of chemicals. A planned efficient water management and irrigation system (drip irrigation) can minimize offsite water-quality impacts. So the impact on water resource is low.

ii) Grazing

To minimize the impact on water the selected grass seed mixture includes stress-tolerant species that can provide a quick and efficient ground cover. So the impact registered is very low.

iii) Beekeeping

The species-rich grassland used incorporates plants that provide protection against wind and water erosion conditions. So when compared with the original arable land use this option does not have an impact on the water resource.

iv) Biodiversity

Vegetation and trees have the potential to protect the surface against water (raindrop impact and run-off), so it is important the landscape elements such as hedgerows, retaining trees along boundaries and the grassland. So no impact is registered.

v) Mowing

Without vegetation the soil is not protected against raindrop impact and run-off. So the impact is high.

7.2.1.3. ***Air resources***

Trees and vegetation are needed to improve the air quality and minimize some of the negative effects of pollutants; they also remove the greenhouse gas i.e. $CO_{2,}$ associated with climate change (Florest Research, 2016).

i) Crops

During establishment of this land use there would be exhaust gas from machinery preparing the ground to receive the crops, also during the harvest the use of machinery will be high. The frequency of cleaning will be higher, so more pollutants will be released. However, when compared with the prior land use the impact is medium.

ii) Grazing

Methane is the second most significant greenhouse gas. It is produced by the normal digestive processes of livestock, and from animal excreta. However, the existing vegetation minimizes the negative effect of the air pollutant. The sheep are controlling the ground vegetation in an organic way, reducing air pollution. So the impact is low.

iii) Beekeeping

As mentioned above the vegetation minimizes the negative effects of pollutants. So this land management does not have an impact on air quality.

iv) Biodiversity

The landscape elements such as hedgerows, the trees on boundaries and the grassland will mitigate the effect of pollution. The human activity is very low. So this land management does not have an impact on the air resource.

v) Mowing

Without vegetation that promotes the reduction of pollutant levels injected into the atmosphere, the quality of the air is poorer. The constant use of machinery (mowing and cleaning) will increase the CO_2 emissions. This has a very high impact on air resources.

7.2.2. Biodiversity Impacts

7.2.2.1 Crops

The crops analysed, runner beans and tomato flowers produce pollen and nectar for a variety of bees, and the cucumbers require bees as main pollinator to produce. The crops will not be grown during the winter and until March the vegetation can be used as habitat for wildlife; this represents more wildlife habitats so more biodiversity. However, during the seeding and harvest the human and machinery activity are high and there will be disturbance to the habitats during this period. So the impact is medium.

7.2.1.2.Grazing

The site is maintained through sheep grazing in the autumn and winter, with no grazing during the spring and summer to allow herbs and flower to set seed, so this provides significant benefits in terms of habitats and wildlife, for insects and other invertebrates. So the impact is low.

7.2.1.3.Beekeeping

The species-rich grassland and wildflower meadows provide nectar sources for honey-bees and other pollinators and supports wildlife, preserving habitats and enhancing biodiversity. Beekeeping is therefore beneficial for biodiversity.

7.2.1.4.Biodiversity

The wildflower meadows attract insects and other invertebrates i.e. butterflies, bees, spiders and millipedes, birds and mammals.

The various options of landscape elements (as described on chapter 6) implemented will enhance biodiversity and support an extensive diversity of wildlife on solar farms, providing food, shelter and habitats. So, there will be no negative impact on biodiversity.

7.2.1.5.Mowing

The mowing during the growing season reduces the diversity of plant species on grassland, subsequently there is less diversity of habitats supporting wildlife and providing food, reduction of nesting covers and reduction of protective cover. Therefore the habitats and quality of wildlife that can be supported by grassland will reduce. In this case there will be a fragmentation of habitats, therefore a loss of wildlife; disturbance of species through noise of human and vehicle presence; and incidental mortality or injury of species. So the impact is very high.

7.2.3. Land-use Impacts

The land use will change due to human activity or when vegetation or biological soil crust is cleared or when soils are disturbed (above or below-ground) to develop the suitable land management (*R.R. Hernandez (2013)).*

7.2.3.1.Crops

The land is currently in agriculture use. Therefore it is not considered that the proposed land management would lead to significant loss of agricultural land as the site will continue to be used for agricultural purposes. So no impact registered.

7.2.3.2.Grazing

The land will continue to be capable of being used for agricultural purposes, as it will be grazed by sheep after construction. The agricultural production will no longer be the predominant use of the site, however, after decommissioning the land will be returned to an agricultural use. So this impact is low and the land quality will be unaffected.

7.2.3.3.Beekeeping

The species-rich grassland and wildflower meadows will protect the soil ensuring that after decommissioning the land can be returned to an agricultural use. The hives will occupy part of the ground, without affecting the land, and the required low activity of human supervision will not impact. So no impact is registered.

7.2.3.4.Biodiversity

Wildflower meadows will not affect the quality of the ground. The land will not be irreversibly developed and it does not involve the permanent loss of agricultural land. The biodiversity will increase and has the additional advantage in that there will not be any human activity and no machinery is needed once the construction is completed. So no impact is registered.

7.2.3.5.Mowing

The constant vegetation clearing will affect the land use, because the soil is not protected from erosion and against raindrop impact and also from run-off impact. Also, the constant human activity and machinery to clean the panels will affect the ground. So the land use is affected and after decommission the land will not return as easily to the previous use.

7.2.4. Socio economic impacts

7.2.4.1. Crops

The seeding and harvesting could be done by local labour, so there will be employment for local workers. However, the constant activity during seeding and harvesting periods and also the frequency of machinery use to clean the panels means more air pollution and noise pollution. However, when compared with the land use prior to construction the impact is low.

7.2.4.2.Grazing

The site with sheep would need to be grazed frequently, and because the sheep will control the vegetation the use of machinery will be avoided, so less pollution and less noise pollution. Grazing is avoided during spring and summer, so provides a green space that can involve the local community (i.e. guide visits, biological studies).

7.2.4.3.<u>Beekeeping</u>

The beekeeping provides a green space that can involve and promote school visits (outdoor class) and the local community. Also, beekeeping can be promoted to boost the keeping of honeybees, which have suffered dramatic declines in recent years. So no impact is registered.

7.2.4.4.<u>Biodiversity</u>

The wildflowers and flowering plants offer several advantages, such as: activities involving the local community i.e. collection of seeds for use at a new location or for sale; an opportunity for education with school visits (biological studies or nature studies to art lessons); and a green space that can be used as a place for leisure and recreation, promoting as well a healthy life.

The site layout has been developed to maximise yield while retaining the existenting trees and hedge cover, maintaining landscape character and reducing visual impact. So no impact socio-economic registered.

7.2.4.5.<u>Mowing</u>

Due to the machinery activity (mowing and the increase clean activity), more noise pollution and more air pollution is registered and less green spaces that the community can get benefits. Although this activity will employ local workers, the socio-economic impact is high.

7.3. Results

Table 2 - Land management option and design features impacts, construction Impact and O&M impacts.

Land management option	**Impact**	**Construction Impact**	**O&M Impact**
	Design features	**Cost**	**cost**
Crops	High	Very high	Very high
Grazing	Low	Low	Very Low
Beekeeping	Low	No impact	Low
Biodiversity	Medium	No impact	Medium
Mowing	No impact	No impact	Very high

The table 2, demonstrate that crops registered high impact in terms of design features and very high on construction and O&M. The impact on design features for grazing is low and very low on construction and O&M. The beekeeping registered low impact in terms of design features and O&M and did not register impact on construction. The biodiversity registered medium impact in terms of design features and O&M but did not register impact on construction. The mowing did not register impact in terms of design features and construction but register very high impact on O&M.

Table 3 – Environment Impacts; Biodiversity, land-use and socio-economic impact

Land management		Environmental Impacts			Other Impacts		
Options		**Soil**	**Water resource**	**Air Resource**	**Biodiversity**	**Land use**	**Socio-ecomic**
Agriculture	Crops	Medium	Low	Medium	Medium	No impact	Low
	Grazing	Low	Very low	Low	Low	Low	Very low
	Breekeeping	No impact	No impact	No impact	No impact	No impact	No impact
Biodiversity		No impact	No impact	No impact low	No impact	No impact	No impact
Mowing		Very high	High	Very high	Very high	High	High

The results demonstrate that the land management crops registered medium impacts on environment and biodiversity (see table 3) and registered low impact in terms of social economic. The grazing registered low environmental impacts (soil and air resource) and very low (water resource) and in terms of biodiversity the impact was low and very low for socio-economic impact. The beekeeping and biodiversity did not register impact. Finally the mowing registered high (water, land use and socio-economic) and very high (soil, air resource and biodiversity) impact.

Chapter 8 –Conclusions and Future Research

This project proposes and discusses the creation of land management options on solar PV sites in the UK. However the suitable option will be determined by the site characteristics, once each site is unique in terms of environment by the location, the pre-existent biodiversity and land use. Therefore the impacts presented and the results are a tool to help the developers in this decision. So this project presented a series of options that can be followed as a way to increase the potential of the PV site, promoting besides generate electricity for the grid can also be a support of biodiversity and agriculture activity.

The study demonstrates that solar farms can provide suitable conditions for agriculture and biodiversity and show significant gains as compared to mowing option, with less environment and social economic impacts. However is recommended the investigation of others microclimatic effects (i.e. wind mitigation, crop and soil temperature changes, latitude) to analyse the crops viability on solar PV. Even the type of land management will influence the biodiversity gains (see table 3), as demonstrated here the land option biodiversity (meadow habitats and boundary features) and beekeeping reveal greater value than crops or grazing. However grazing land can still provide benefits in terms of wildlife.

The grazing sheep is beneficial to be continued operation of solar farms on agriculture land, (land quality will be unaffected) sheep will control the vegetation so the use of machinery will be avoided, therefore less air pollution, less noise pollution and reduction of the cost on O&M.

The beekeeping may be attractive to site PV, because it does not require any specific design feature and during the construction phase no impact was registered. Also during the O&M the human disturb is low, it only requires occasional maintenance (inspect and clean the hives). The frequency of panels cleaning is low, because the vegetation can control the dust.

While mowing may be the most common method of vegetation control, any of the land management options will be a very good alternatives to that. Because they will be preserve and boost the biodiversity and the productivity of the land, while generate a clean energy. So it can be concluded that land management use on solar farms deliver measurable benefits to biodiversity and social economic gains (i.e. employment of local workers) and also enhance the environmental quality of neighbourhoods, with creation of green spaces that could involve the local community (i.e. school visits, walks on surrounding areas).

In order to give continuity and improvement to this project is suggested the application of these impacts analysing other criteria (i.e. financial plan, location) so that way a suitable land management option can be chosen. This way the project would help to promote guidelines in terms of agriculture and biodiversity to PV developers and planners.

Bibliography

Belfiore, f. (2013). *RISKS AND OPPORTUNITIES IN THE OPERATION OF LARGE SOLAR PLANTS.* Retrieved October 28, 2016, from Engineering Earth's Development, Preserving Earth's Integrity: http://www.golder.ca/en/modules.php?name=Publication&op=showlivepdf&sp_id=300&lang_id=3

Bumblee Conservation Trust. (2016). *Habitats*. Retrieved November 10 , 2016, from Bumblee Conservation Trust: http://bumblebeeconservation.org/about-bees/habitats/

Carvell, C. (2002). Habitat use and Conservation of Bumblebees (Bombus spp.) under different grassland management regimes. *Biological Conservation* , 33-49.

Cuff, M. (2016). *DECC figures reveal 93 per cent fall in UK solar deployment 2016*. Retrieved September 26, 2016, from Business green: http://www.businessgreen.com/bg/news/2453010/decc-figures-reveal-93-per-cent-fall-in-uk-solar-deployment

DEFRA. (2016). *Farming Statistics Final crop areas and cattle, sheep and pig populations at 1 June 2016 - England* . Retrieved November 2, 2011, from Department for Environment Food & Rural Affairs: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/552759/structure-june16-final-eng-15sep16.pdf

Dupraz, C. et al. (2011). Combination Solar Photovoltaic panels and foof crops for optimising land use: Towards new agrivoltaic schemes. In *Renwable Energy* (36 ed., pp. 2725-2732). France.

EC Energy Strategy . (2016). *2030 Energy Strategy*. Retrieved eSptember 10, 2016, from European Comission: https://ec.europa.eu/energy/node/163accessed

EC Rewable Energy. (2016). *Rewable Energy*. Retrieved September 10, 2016, from European Comission: https://ec.europa.eu/energy/en/topics/renewable-energy

EEA. (2016). *Renewable Energy in Europe 2016, Recent Growth an Knock on effects- EEA Report*. Retrieved June 13, 2016, from European Environment Agency : http://www.eea.europa.eu/publications/renewable-energy-in-europe-2016

European Union Maps. (2011). *United Kingdom Solar Map 2011*. Retrieved November 2, 2016, from European Union Maps: http://www.europeanunionmaps.com

FAO . (2016). *Irrigation Water Management: Irrigation methods*. Retrieved November 12, 2016, from Food and Agriculture Organization of the United Nations: http://www.fao.org/docrep/S8684E/s8684e07.htm

Fitzpatrick, D. (2014). Uk Legislative Framework for Renewable Energy. In D. Fitzpatrick, *Clean Energy Uk Finance Guide 2014.* England: Clean Energy Pipeline.

Florest Research. (2016). *Erosion Control*. Retrieved November 12, 2016, from Florest research: http://www.forestry.gov.uk/fr/urgc-7EDGRJ

GOV.UK. (2016). *Solar Photovoltaic Deployment 2014*. Retrieved September 26, 2016, from Gov.Uk: https://www.gov.uk/government/statistics/solar-photovoltaics-deployment

Greenheath. (2016). *Solar Farm Operations & Maintenance*. Retrieved October 15, 2016, from Greenheath: http://www.greenheath.co.uk/solar-farm-management/

HCCMPW. (2016). *Grassland Management* . Retrieved October 10 , 2016, from HCCMPW: http://www.hccmpw.org.uk/medialibrary/publications/HCC_Grassland_Management_ENG.pdf

Kellemberg, J. (2015). *Utlity-Scale Solar Photovoltaic Power Plants. A Project Developer's Guide.* England: International Finance Corporation.

Lightsource. (2016). *Lightsource Leads Way in UK Solar O&M with New PV Panel "Clean Machine"*. Retrieved October 28, 2016, from Lightsource: http://www.lightsource-re.co.uk/news/2016/04/lightsource-leads-way-in-uk-solar-om-with-new-pv-panel-clean-machine/

Marrou, H.; Dufour, J.; Wery, J. (2013). How does a shelther of solar panels influence water flows in a soil-crops system? *Eurpean Journal of Agronomy*.

Marrou, H.; et al. (2012). Productivity and Radiation use efficiency of lettuce grown in the partial shade of photovoltaic panels. *European Journal of Agronomy* .

Miller, A.; Lumby, B. (2015). A guide for developers and investors. . In I. F. Corporation.

Naika, S. et al. (2005). *Cultivation of Tomato*. Retrieved October 27, 2016, from Agromisa Foundation and CTA: http://journeytoforever.org/farm_library/AD17.pdf

National Encylopedia. (2016). *Fauna and Flora in UK*. Retrieved October 2, 2016, from National Encylopedia: http://www.nationsencyclopedia.com/Europe/United-Kingdom-FLORA-AND-FAUNA.html#ixzz4LweDOooo

Natural England. (2012). *Agricultural Land Classification: Protecting the Best and Most Versatile Agricultural Land*. Retrieved October 25, 2016, from Natural England: http://publications.naturalengland.org.uk/file/4424325

Natural England. (2012). *Agricultural Land Classification: protecting the best and most versatile agriculture land.* Retrieved October 29, 2016, from Natural England: http://publications.naturalengland.org.uk/file/4424325

Ofgem RO. (2016). *About the RO*. Retrieved September 21, 2016, from Ofgem : https://www.ofgem.gov.uk/environmental-programmes/ro/about-ro

OMLET. (2016). *Season Spring*. Retrieved November 15, 2016, from OMLET: https://www.omlet.co.uk/guide/bees/bee_season/

Parker, G. (2014). *Biodiversity Guidance for Solar Developments.* England: Building Research Establishment (BRE) National Solar Centre.

Pleasant, B. (2012). *Gardening With Vegetables That Grow in Shade*. Retrieved October 20, 2016, from Growveg: https://www.growveg.com/guides/gardening-with-vegetables-that-grow-in-shade/

Prata, D. (2016). *Uk to miss 2020 Renewable Energy targets concludes National Grid*. Retrieved September 26, 2016, from Solar Power Portal: http://www.solarpowerportal.co.uk/news/uk_to_miss_2020_renewable_energy_targets_concludes_national_grid

R.R. Hernandez et al. (2013). Environmental impacts of utility-scale solar energy. *Science Direct*, 29 (2014) 766–779.

Royal Horticultural Society . (2016). *Runner Beans*. Retrieved November 4, 2016, from Royal Horticultural Society : https://www.rhs.org.uk/advice/grow-your-own/vegetables/runner-beans?type=v

RSPB. (2016). *Value of Hedgerows for Wildlife*. Retrieved September 19, 2016, from The Royal Society for the Protection of Birds: http://www.rspb.org.uk/ourwork/conservation/advice/farmhedges/value.aspx

Sanderson, S. (2016). *How to grow cucumbers*. Retrieved October 21, 2016, from Thompson&Morgan : http://www.thompson-morgan.com/how-to-grow-cucumbers

Scurlock, J. (2013). *Agricultural Good Pratice Guidance for Solar Farms.* Building Research Establishment (BRE).

Southill Charlbury. (2015). *Biodiversity Management: Proposed Solar Farm, Southill, Charlbury.* UK: Wychwood Biodiversity.

Stud Farm . (2015). *Environmental Statement* . Retrieved October 28, 2016, from newark&sherwooddc: https://publicaccess.newark-sherwooddc.gov.uk/online-applications/files/F5381BBC2031BCEE47B5D8BF928982C1/pdf/15_00324_FULM-ENVIRONMENTAL_STATEMENT_3_-_PROJECT_DESCRIPTION-522900.pdf

Zipp, k. (2013). *What is a solar operations and maintenance plan?* Retrieved December 09, 2015, from Solar Power World: www.solarpowerworldonline.com/2013/03/what-is-a-solar-operations-and- maintenance-plan

Annexes

Annex 1

Proposed solar farm with Biodiversity use

Source: (Lightsource, 2016)