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# The Southern Uplands Partnership Mapping Renewable Energy Opportunities in the Scottish Borders

## Etrick and Yarrow Valleys

30 August 2016



## Report Summary

This report details the process of identifying renewable energy opportunities within the Ettrick and Yarrow Valleys on behalf of the Southern Uplands Partnership (SUP). A Geographical Information System (GIS) approach has been undertaken to determine the existing physical and environmental constraints to renewable energy development in the area and to determine suitable opportunity areas for further assessment.

The assessment has been carried out as a pilot study and makes use of publically available data in order to demonstrate that this process can be repeated for other areas within the Scottish Borders region and Scotland.




The outcome of the assessment provides opportunity maps for three established renewable energy technologies: hydro power, ground mounted solar PV and wind energy. The maps indicate those opportunity areas which have the highest potential for further development based on the available renewable resource, access suitability and proximity to the local grid network.



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## Glossary

Abbreviation or Term	Definition
.shp	Shapefile
DEM	Digital Elevation Model
GIS	Geographical Information System
ha	Hectares
NOABL	Numerical Objective Analysis Boundary Layer
OS	Ordnance Survey
PV	Photovoltaic
SAC	Special Areas of Conservation
SNH	Scottish Natural Heritage
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
Study Area	Ettrick and Yarrow Valleys
SUP	Southern Uplands Partnership
WTG	Wind Turbine Generator



## 1 Introduction

The Southern Uplands Partnership (SUP) commissioned SgurrEnergy to undertake a desk-based assessment of renewable energy opportunities in the Ettrick and Yarrow Valleys, shown in Figure 1-1 below.



**Figure 1-1: Ettrick and Yarrow Valleys Study Area**

The objective of the assessment is to provide SUP with map based information of potential renewable energy opportunities that can inform the successful development of community owned and other locally focussed renewable energy projects.

This assessment forms a pilot study with the aim of developing similar opportunity maps in the wider Scottish Borders region. The opportunity maps focus on three established renewable energy technologies:

- Wind Power
- Solar Photovoltaic (PV)
- Run of River Hydro

The remainder of this report details the methodology used to identify the opportunity areas for these areas and the scoring methodology used to identify the most suitable locations.





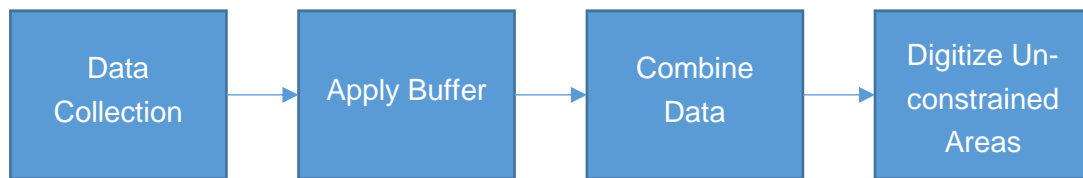
## 2 Opportunity Area Mapping

A high level constraints mapping exercise was undertaken to determine the physical and environmental constraints to renewable development in the Ettrick and Yarrow Valleys.

In order to ensure the constraints mapping process can be repeated for other regions only publically available information was used. This information was obtained in the form of georeferenced shapefiles (.shp) and used to construct technology specific constraint maps for the study area.

The majority of these constraints are relevant to all technologies. Where applicable, technology specific buffers were applied using editing tools available with GIS software. For example, a larger exclusion distance from occupied buildings was required for wind energy due to potential noise and shadow flicker effects.

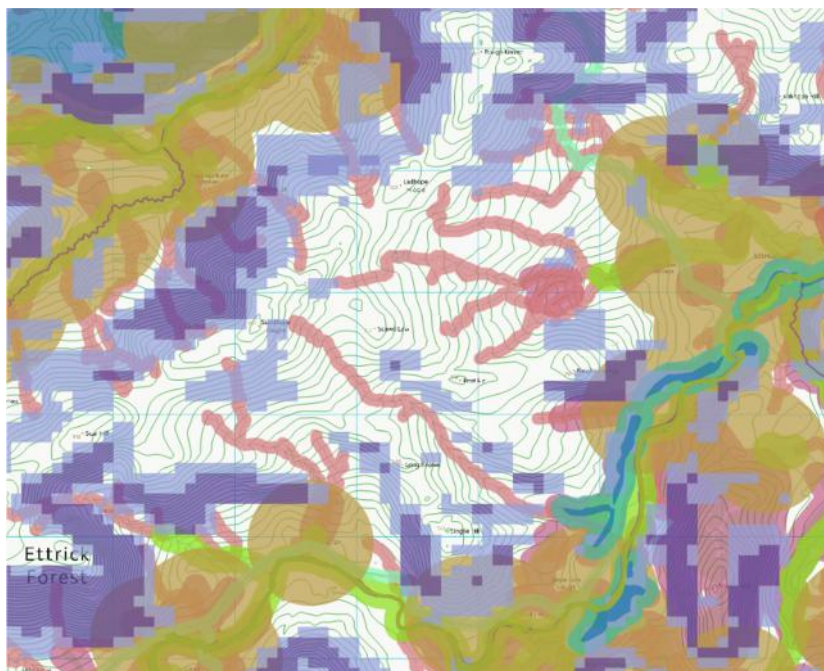
The constraint maps were constructed following the process shown in Figure 2-1 below.



**Figure 2-1: Constraint Mapping Process**

An example of the constraints map is shown in Figure 2-2 below. This identifies areas considered unsuitable for renewable energy development such as proximity to hydrological features, proximity to buildings and areas of adverse steep slopes. The unconstrained areas for each technology were digitized to .shp files and included in the opportunity maps provided in Appendix A.





**Figure 2-2: Example Constraints Map**

The following details each of the constraints applied to the study area for each technology.

## 2.1 Wind Energy

The potential landscape and visual impact of wind energy development means that significant constraints exist to development. Planning guidance for wind turbine development in the Scottish Borders area shows that there is generally a low capacity for wind turbine development within the Ettrick and Yarrow Valleys.

As such, the opportunity mapping assessment has only considered potential development areas for farm small scale WTGs (up to 50 kW in capacity) as they will have a lower landscape and visual impact.

It is advisable to ensure that WTGs are at least toppling distance from infrastructure such as buildings, roads, railways and high voltage power lines. Consequently, appropriate buffers have been applied to any such features. A nominal buffer distance of 500m has been applied to any nearby buildings considered sensitive to noise and shadow flicker impacts from wind turbines.

The constraints used to develop the opportunity map for wind energy are detailed in Table 2-1. Small areas or 'specks' were removed from the dataset by limiting the size of the opportunity areas to a minimum site area of 1 ha. The opportunity map for wind energy is shown in Drawing 001.



**Table 2-1: Wind Energy Constraints**

Category	Consideration	Description	Constraint applied	Data Source
Cultural Heritage	Category A listed Buildings	Buildings noted for their special archaeological and historical interest.	Avoid development within 500m	Historic Scotland
	Scheduled Ancient Monuments	Nationally important archaeological sites or historic buildings.	Avoid development within 100m	
	Battlefields Inventory	List of nationally important battlefields in Scotland.	Avoid development within 100m	
	Conservation Areas	Areas of architectural or historic value.	Avoid development within area.	
	Gardens and Designed Landscapes	Landscapes and gardens considered to be valuable assets at national level.	Avoid development within area.	
Ecology	Site of Special Scientific Interest (SSSI)	A European designation for sites designated under the EC Habitats Directive.	Avoid development within area.	Scottish Natural Heritage (SNH)
	Special Areas of Conservation (SAC)	A European designation for sites designated under the EC Habitats Directive.	Avoid development within area.	
	Special Protection Area (SPA)	A European designation for areas of importance to wild birds under the EU Birds Directive.	Avoid development within area.	



Category	Consideration	Description	Constraint applied	Data Source
	Ancient Woodland	Ancient, long-established or semi-natural woodlands of national importance.	Avoid development within area.	
	Areas of Wild Land	Nationally important wild landscapes afforded strong protection.	Avoid development within area.	
Hydrology/Geology	Surface Water	Rivers, burns, lakes etc.	Avoid development within 50m.	OS OpenData
	High Class Soil	Areas of deep peat, carbon rich soil and priority peatland habitat	Avoid development within area.	Scottish Natural Heritage (SNH)
Landscape	Special Landscape Area (SLAs)	Locally designated sensitive landscape	Avoid development within area.	Scottish Borders Council
Topography	Steep Slopes	Derived from Digital Elevation Model (DEM) created from OS Contour data data.	Avoid steep slopes greater than 10 degrees.	OS OpenData
General	Core Paths	Public right of way	Avoid development within 100m.	OS OpenData
	Occupied buildings	Any buildings or urban areas shown on 1:25,000 OS map.	Avoid development within 500m.	
	Woodland	Any woodland shown on 1:25,000 OS map.	Avoid development within 100m.	
	Public Roads	All roads marked on 1:25,000 OS map	Avoid development within 100m.	
Wind Farms	Cumulative development	All operational and planned wind turbine developments	Avoid development within area.	Scottish Natural Heritage (SNH)



## 2.2 Solar PV

The constraints mapping exercise for solar PV has focused on ground mounted PV opportunities. Smaller scale roof mounted PV has not been considered within this assessment as a sufficient level of detail was not considered to be publically available.

The development of ground mounted solar energy systems is less contentious from a landscape and visual point of view and therefore is less constrained when compared to wind energy. One of the main considerations was to ensure that potential development opportunity areas were located on a flat area of land with a south facing slope. A Digital Elevation Model (DEM) has been produced using OS contour data in order to determine the aspect of each 100 m x 100 m square area. Those areas with a north facing aspect (275 – 90) have been included as a constraint to development.

Where possible, suitable buffers have been applied to some constraints in order to minimise potential shading effects on the opportunity areas. A more detailed effect of local topography shading will need to be carried out as part of further feasibility work.

The constraints used to develop the opportunity map for wind energy development are detailed in Table 2-2. Small areas or 'specks' were removed from the data set by limiting the size of the opportunity areas to a minimum site area of 1 ha. The opportunity map for solar PV energy is shown in Drawing 002.



**Table 2-2: Solar Energy Constraints**

Category	Consideration	Description	Constraint applied	Data Source
Cultural Heritage	Category A listed Buildings	Buildings noted for their special archaeological and historical interest.	Avoid development within 500m	Historic Scotland
	Scheduled Ancient Monuments	Nationally important archaeological sites or historic buildings.	Avoid development within 100m	
	Battlefields Inventory	List of nationally important battlefields in Scotland.	Avoid development within 100m	
	Conservation Areas	Areas of architectural or historic value.	Avoid development within area.	
	Gardens and Designed Landscapes	Landscapes and gardens considered to be valuable assets at national level.	Avoid development within area.	
Ecology	Site of Special Scientific Interest (SSSI)	A European designation for sites designated under the EC Habitats Directive.	Avoid development within area.	Scottish Natural Heritage (SNH)
	Special Areas of Conservation (SAC)	A European designation for sites designated under the EC Habitats Directive.	Avoid development within area.	
	Special Protection Area (SPA)	A European designation for areas of importance to wild birds under the EU Birds Directive.	Avoid development within area.	



Category	Consideration	Description	Constraint applied	Data Source
	Ancient Woodland	Ancient, long-established or semi-natural woodlands of national importance.	Avoid development within area.	
	Areas of Wild Land	Nationally important wild landscapes afforded strong protection.	Avoid development within area.	
Hydrology/Geology	Surface Water	Rivers, burns, lakes etc.	Avoid development within 50m.	Ordnance Survey (OS) Open Map data
	High Class Soil	Areas of deep peat, carbon rich soil and priority peatland habitat	Avoid development within area.	Scottish Natural Heritage (SNH)
Topography	Slope Angle	Derived from Digital Elevation Model (DEM) created from height data.	Avoid steep slopes greater than 10 degrees. Avoid areas with aspect direction of >270° and < 90°.	OS OpenData
General	Core Paths	Public right of way.	Avoid development within 100m.	OS OpenData
	Occupied buildings	Any buildings or urban areas shown on 1:25,000 OS map.	Avoid development within 100m.	
	Woodland	Any woodland shown on 1:25,000 OS map.	Avoid development within 100m.	
	Public Roads	All roads marked on 1:25,000 OS map	Avoid development within 100m.	



## 2.3 Hydro

The mapping exercise focused on potential run of river hydro systems consisting of an intake point on a river with water diverted into a pipeline and thereafter to a turbine house lower down the river. The viability of such hydro schemes is dependent on a number of key factors notably catchment size, rainfall, available head (height differential between intake and powerhouse) and local topography.

The key consideration from a planning and environmental perspective is the ecological impact of a hydro scheme as the abstraction of water has the potential to negatively impact on ecologically sensitive waterbodies. The mapping exercise has excluded any ecologically designated water bodies (e.g. SSSI, SAC or SPA) from the potential intake and turbine house locations.

The constraints used to develop the opportunity map for hydro energy development are detailed in Table 2-3. Small areas were removed from the data set by excluding any river systems with a combined length of under 5 km. The opportunity map is shown in Drawing 003.





**Table 2-3: Hydro Energy Constraints**

Category	Consideration	Description	Constraint applied	Data Source
Cultural Heritage	Scheduled Ancient Monuments	Nationally important archaeological sites or historic buildings.	Avoid development within 100m	Historic Scotland
	Battlefields Inventory	List of nationally important battlefields in Scotland.	Avoid development within 100m	
	Conservation Areas	Areas of architectural or historic value.	Avoid development within area.	
	Gardens and Designed Landscapes	Landscapes and gardens considered to be valuable assets at national level.	Avoid development within area.	
Ecology	Site of Special Scientific Interest (SSSI)	A European designation for sites designated under the EC Habitats Directive.	Avoid development within area.	Scottish Natural Heritage (SNH)
	Special Areas of Conservation (SAC)	A European designation for sites designated under the EC Habitats Directive.	Avoid development within area.	
	Special Protection Area (SPA)	A European designation for areas of importance to wild birds under the EU Birds Directive.	Avoid development within area.	



Category	Consideration	Description	Constraint applied	Data Source
	Ancient Woodland	Ancient, long-established or semi-natural woodlands of national importance.	Avoid development within area.	
	Areas of Wild Land	Nationally important wild landscapes afforded strong protection.	Avoid development within area.	
Hydrology/Geology	High Class Soil	Areas of deep peat, carbon rich soil and priority peatland habitat	Avoid development within area.	Scottish Natural Heritage (SNH)



### 3 Energy Resource Mapping

In order to identify the most suitable opportunity areas, the available renewable resource was mapped with GIS software.

Each of the shapefiles produced are linked to a table in GIS software which details the individual attributes of each opportunity area. The available resource has been included in this table and a value assigned for each area.

The following describes how the available resource has been applied to the opportunity maps.

#### 3.1 Wind Energy

The available wind resource is based on the national wind speed database NOABL (Numerical Objective Analysis Boundary Layer) and gives estimates of average wind speeds at 10, 20 and 45 m Above Ground Level (AGL).

The NOABL database is available at 1 x 1 km grid resolution. An example of the available wind resource at 45m over portion of the study area is provided in Figure 3-1 below.

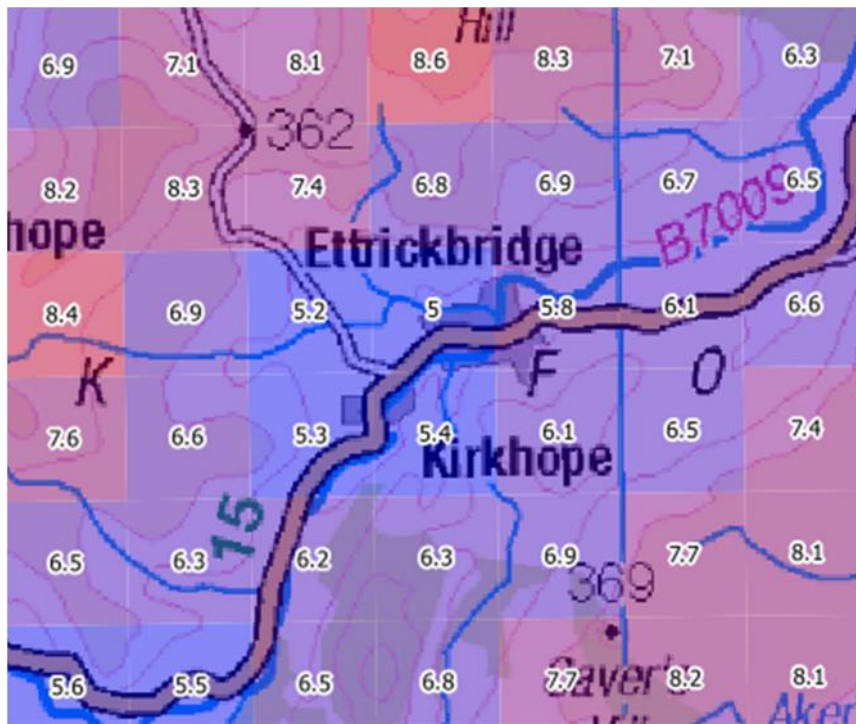


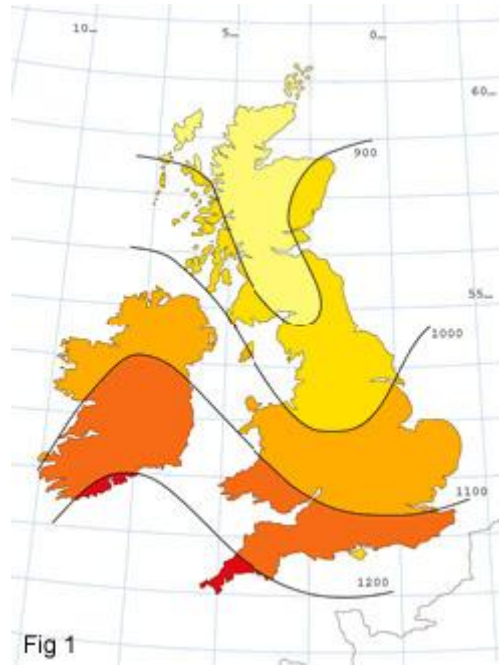
Figure 3-1: NOABL wind speed estimates at 45m AGL (m/s)

The opportunity areas shown in Drawing 001 have been edited based on the NOABL score for each area using the intersect tool in GIS software.



### 3.2 Solar Energy

The available solar energy resource is known as solar irradiance and is measured as power per unit area received from the sun ( $\text{kW}/\text{m}^2$ ). The solar irradiance is dependent on the geographical position of the site and is illustrated in Figure 3-2 below.



**Figure 3-2: UK and Ireland Solar Irradiance ( $\text{kWh}/\text{m}^2$ )**

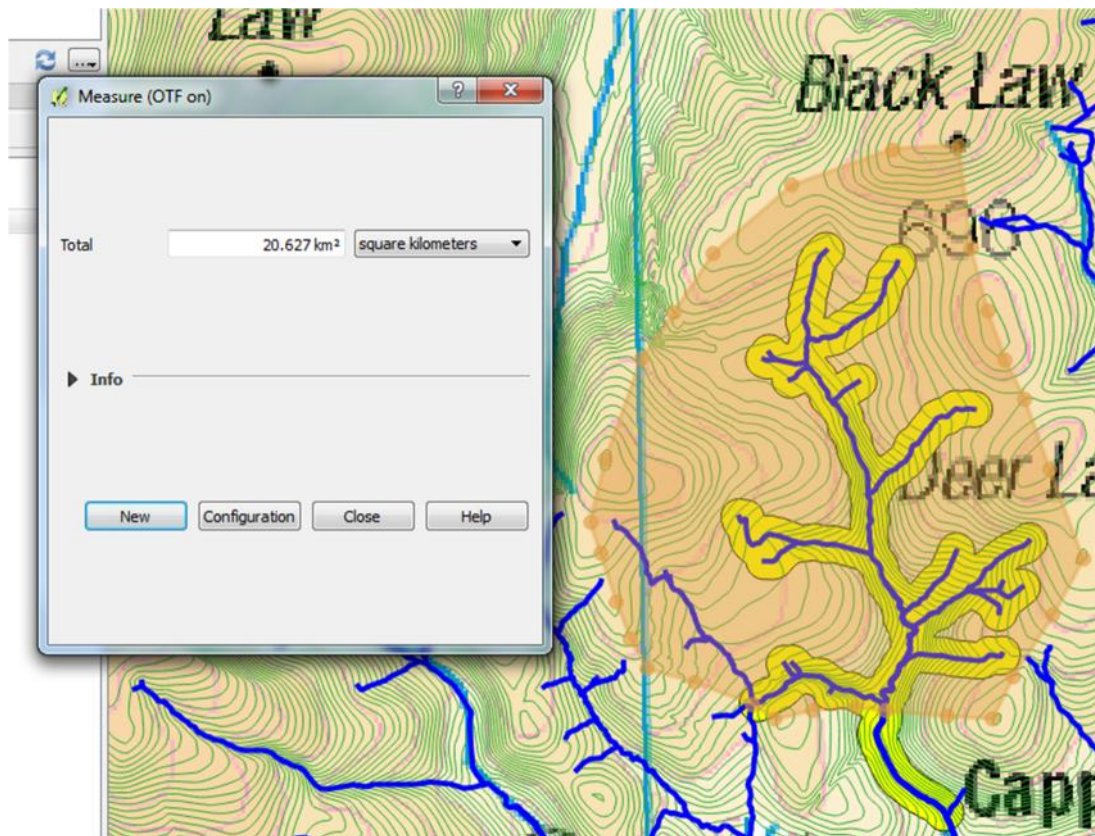
For the purposes of this assessment, the solar resource is considered to be consistent across the study area and is expected to be in the region on  $900 \text{ kW}/\text{m}^2$ . Localised impacts on the available resource such as topographical shading are outside the scope of this assessment and should be assessed as part of further feasibility work.

### 3.3 Hydro Resource

The potential hydro resource is difficult to accurately determine as part of a high level assessment. The potential power available from a river system will be dependent on a number of factors such as the available catchment area, available head, specific topographical characteristics (which can influence intake location and potential pipeline route), annual rainfall and the effect of ground absorption.

For the purposes of this opportunity mapping exercise, the potential energy capacity of each of the identified opportunity areas has been estimated. This has been based on achieving the maximum catchment area for each river system. An example of one of the opportunity areas is shown in Figure 3-3 below.





**Figure 3-3: Example of measured catchment surrounding hydro opportunity area**

This example shows an available head of approximately 30m. This height is taken from the potential intake location to the powerhouse, which is assumed to be located at the furthest point downstream within the opportunity area. As no rainfall data is available, an average rainfall of 3.5 m/year has been estimated and a run off coefficient of 0.4 has been used to determine the flow rate. The available generation capacity has then been calculated using the following formula.

$$P = H \times F \times g$$

Where:

- P = Power (W)
- H = Head (m)
- F = Flow rate (l/s)
- g = acceleration due to gravity (9.81 m/s)

At an assumed system efficiency of 60%, the estimates generation capacity available from this river system is estimated at 165 kW. The estimated hydro power capacity has been added to the shapefile attribute table for each opportunity area.



It should be noted that this is an extremely high level assessment and used only for the purpose of indicating potential hydro opportunity areas. Further feasibility assessment will be required to determine the potential generation capacity and should utilise measured flow rates and should consider other variables such as head losses and ground absorption. Further configurations should also be considered where the available head height can be increased.



## 4 Opportunity Area Scoring

A site scoring methodology was developed to determine those opportunity areas considered to have the highest potential for further feasibility assessment.

In order to develop a scoring system that can be repeated in other regions, it was important to score sites based on publically available data which was measurable using GIS software. It was decided that each opportunity area shall be scored based on 3 key variables:

- Access suitability
- Grid proximity
- Available resource

Each opportunity area has an attribute table linked to its shapefile. These three variables were added to the attribute table in order to calculate the overall score for each opportunity area.

The final score of each opportunity area is ranked from 1 – 5 and based on a weighted sum of these variables. The following details how these variables are measured and describes the final scoring methodology.

### 4.1 Access Suitability

The select by location tool in GIS software selects features based on their location relative to features in another shapefile. Individual features were selected from the opportunity area's shapefile within a specified distance of the road network shapefile<sup>1</sup> and scored in accordance with Table 4-1 below.

**Table 4-1: Access Score**

Distance to Public Road	Score
<100 m	5
<250 m	4
<500 m	3
<1 km	2
>1km	1
Restricted access	0

<sup>1</sup> Obtained via OS Open Data



## 4.2 Grid Proximity

Individual features were selected from the opportunity area's shapefile within a specified distance of the distribution network shapefile<sup>2</sup> and scored in accordance with Table 4 1 below.

**Table 4-2: Grid Connection Score**

Distance to nearest distribution line	Score
<250 m	5
<500 m	4
<1 km	3
<2 km	2
>2 km	1

## 4.3 Available Resource

The resource score for each technology is detailed below.

Table 4-3 below details the available wind resource score for each opportunity area.

**Table 4-3: Wind Resource Score**

NOABL estimate at 40m AGL	Score
>7.5 m/s	5
>7.0 m/s	4
>6.5 m/s	3
>6.0 m/s	2
<6.0 m/s	1

<sup>2</sup> Obtained from Scottish Power Energy Networks (SPEN)





### 4.3.1 Solar Resource

As described in Section 3, the available solar resource is considered to be consistent across the study areas. A score of 3/5 has been applied to each of the identified opportunity areas.

### 4.3.2 Hydro resource

As detailed in Section 3 the hydro resource score is based on the estimated available generation capacity at each opportunity area. This estimation is based on maximising the available catchment area for each river system, however this means that the available head is generally considered to be between 10m – 60m. An increased in head may be possible at each location with a reduced catchment area and therefore reduction in flow rate. The impact of this on the expected generation will require further assessment.

Table 4-4 below details the available resource score for each opportunity area.

**Table 4-4: Hydro Resource Score**

Estimated Generation Capacity	Score
<25 kW	1
<50 kW	2
<75 kW	3
<100 kW	4
>100 kW	5

### 4.4 Site Score

A total site score of 1 - 5 is based on the sum of the grid, access and resource score and is weighted in accordance with Table 4-5 below.

Considering the high-level nature of this assessment, the available resource will be the most important aspect to consider at this stage. A low weighting has been applied to the proximity to the grid network as alternative opportunities could be available such as the creation of electrical demand or a private microgrid.



**Table 4-5: Total Score**

<b>Variable</b>	<b>Weighting</b>	<b>Maximum Score</b>
Grid	20%	1
Access	30%	1.5
Resource	50%	2.5
<b>Total</b>		<b>5</b>



## 5 Results and Conclusions

The opportunity areas for each technology are provided in Drawings 001 – 003 in Appendix A.

The mapping study has shown that the Ettrick and Yarrow Valleys are heavily constrained with regards to landscape and visual impacts. However, there are areas considered suitable for potential renewable energy development, particularly ground mounted solar PV, which provides a good opportunity to install a large amount of renewable generation capacity. The opportunity areas identified for wind power are considered to be limited to “farm scale” developments (WTGs of approx. 50k W) due to local planning restrictions. Potential hydro power opportunities will generally be of a smaller scale due to limited resource and ecological constraints in the region.

Further site specific investigation will be required to determine the suitability of the opportunity areas, particularly with regards to grid connection issues. The distribution network in the area is heavily constrained and innovative solutions should be explored in order to accommodate additional generation.

The opportunity mapping study has focused on readily available information and a simple repeatable process has been developed so that other opportunity areas can be assessed.



## Appendix A Opportunity Maps



## Appendix B Data Sources

Data	Source	Link
Background mapping	Ordnance Survey - OS Vector Map District	<a href="http://www.ordnancesurvey.co.uk">www.ordnancesurvey.co.uk</a>
Height data	Ordnance Survey – OS Terrain 50	<a href="http://www.ordnancesurvey.co.uk">www.ordnancesurvey.co.uk</a>
Scheduled monuments ancient	Historic Scotland	<a href="http://portal.historicenvironment.scot/">http://portal.historicenvironment.scot/</a>
Listed buildings	Historic Scotland	<a href="http://portal.historicenvironment.scot/">http://portal.historicenvironment.scot/</a>
Battlefield inventory	Historic Scotland	<a href="http://portal.historicenvironment.scot/">http://portal.historicenvironment.scot/</a>
Conservation areas	Historic Scotland	<a href="http://portal.historicenvironment.scot/">http://portal.historicenvironment.scot/</a>
Sites of Special Scientific Interest (SSSI)	Scottish Natural Heritage	<a href="http://gateway.snh.gov.uk/natural-spaces/">http://gateway.snh.gov.uk/natural-spaces/</a>
Special Areas of Conservation (SAC)	Scottish Natural Heritage	<a href="http://gateway.snh.gov.uk/natural-spaces/">http://gateway.snh.gov.uk/natural-spaces/</a>
Special Protection Areas (SPA)	Scottish Natural Heritage	<a href="http://gateway.snh.gov.uk/natural-spaces/">http://gateway.snh.gov.uk/natural-spaces/</a>
Landscape Character Types (LCTs)	Scottish Natural Heritage	<a href="http://gateway.snh.gov.uk/natural-spaces/">http://gateway.snh.gov.uk/natural-spaces/</a>
Soil data	Scottish Natural Heritage	<a href="http://gateway.snh.gov.uk/natural-spaces/">http://gateway.snh.gov.uk/natural-spaces/</a>
Roads	Ordnance Survey – OS Open Map Local	<a href="http://www.ordnancesurvey.co.uk">www.ordnancesurvey.co.uk</a>
Core paths	Ordnance Survey – OS Open Map Local	<a href="http://www.ordnancesurvey.co.uk">www.ordnancesurvey.co.uk</a>
Surface water	Ordnance Survey – OS Open Map Local	<a href="http://www.ordnancesurvey.co.uk">www.ordnancesurvey.co.uk</a>



Data	Source	Link
Buildings	Ordnance Survey – OS Open Map Local	<a href="http://www.ordnancesurvey.co.uk">www.ordnancesurvey.co.uk</a>
Woodland	Ordnance Survey – OS Open Map Local	<a href="http://www.ordnancesurvey.co.uk">www.ordnancesurvey.co.uk</a>
Areas of Wild Land	Scottish Natural Heritage	<a href="http://gateway.snh.gov.uk/natural-spaces/">http://gateway.snh.gov.uk/natural-spaces/</a>
Ancient woodland	Scottish Natural Heritage	<a href="http://gateway.snh.gov.uk/natural-spaces/">http://gateway.snh.gov.uk/natural-spaces/</a>
Wind resource	NOABL Wind Speed database	
Grid network	Scottish Power Energy Networks (SPEN) Heat Maps	<a href="mailto:GettingConnected@ScottishPower.com">GettingConnected@ScottishPower.com</a>

