Sustainability and Renewable Energy Sources for Greenhaugh Hall, NE48 1PP

Greenhaugh Hall is a C19th ten-bedroom detached house set within 42 acres, with circa 13 acres of grazing land and 29 acres of woodland. Outbuildings comprise 3 timber-construction Stables, a stone Coach House and stone Dog Kennels. The property falls within the Northumberland National Park.

An initial survey has been carried out to investigate the potential for renewable energy generation on-site, with a view to reducing the carbon intensity of the property's energy use.

A. HISTORIC ENERGY CONSUMPTION AND CARBON EMISSIONS PROFILE

The current EPC rates the property's energy efficiency at band F, reflecting to a great extent thermal inefficiency consistent with a single skinned property of this age. This compares to an average rating in England and Wales for a dwelling of band D. Thermal improvements to the fabric of the building will offer some small opportunity for an improvement in energy efficiency rating, although planning restrictions, cost and a wish to avoid internal upheaval may limit the scope of works possible. Whilst efficiency improvements are a key first step to improving the rating, the most impactful opportunity to do so for a property of this age is through on-site 'renewable energy' heat and electricity generation.

EPC estimation of current annual heat load is 110,886 kWh for space heating and 3,229 for hot water, which equates to 14,000 litres of heating oil assuming a boiler efficiency of 80%. Electricity consumption for a property of this size is likely to be in the region of 10,000 kWh (vs an average for a 3 bedroom dwelling of 3,800 kWh).

The projected annual runnings costs and carbon emission profile is summarised below:

	kWh	**Quantity**	**Cost / £** (at current market prices)	**Carbon conversion factor** ($kgCO_2e/kWh$) [ref. Carbon Trust]	**Carbon emissions** ($kgCO_2e$)
Electricity	10,000	-	1,250	0.44548	4,455
Oil (assuming boiler efficiencies of 80%)	142,644	14,000 litres	8,400	0.24555	35,026

It is worth noting that the previous owner has confirmed electricity bills in line with the above but oil bills at 50% of this figure. This can be attributed to partial heating of the house, and supplementary heating through the use of the large wood burner and coal burning in the downstairs open fires. The occupancy profile of the Land of Joy is likely to require a level of heating closer to that reflected in the table above and possibly more with the higher hot water demands.

It can be seen that the carbon impact of heating the property is in the order of 8 times greater than that of electricity consumption. This factor is likely to increase with the larger numbers of people on site, resulting in a greater hot water heat load. It is therefore clear that the greatest impact on carbon emission reduction for the site will be the replacement of the current heating system with a low carbon alternative.

B. CHOOSING THE OPTIMUM RENEWABLE HEAT SOLUTION

Existing heat provision and desktop heat load assessment

The property is currently served for heating as follows:

1. Main house: Oil boiler - Worcester Danesmoor Utility 32-50kW
2. Main house: Kitchen range (oil) - 17.5kW Stanley Superstar Range Cooker
3. Main house: wood burner - 12kW
4. Cottage: Oil boiler Boulter Camray 12-30kW

An initial desktop survey, using a Google Earth footprint of the property of 311m^2 and assuming a typical heat loss parameter for a house of this age of 4.05 W/m^2 ºC, estimates a specific heat loss of the building of 2,519 W/ºC. Assuming a design minimum temperature of -3.4ºC and internal temperature of 21ºC a conservative boiler sizing of 60-70kW for the house (and cottage) alone is anticipated. Whilst this an early ballpark estimate, it presents a likely indication as to why the main house boiler has been supplemented by other heat sources.

A replacement renewable energy heating source will need to sized to deliver the additional heat load to the nearby outbuildings in anticipation of their being converted to residential use. Conversion will need to meet existing building regulations for thermal efficiency. A heat source of up to 100kW may be required to meet this additional heat load and that of the main building. A more detailed analysis is required to determine the optimum sizing.

Renewable heat

The application of **ground source heat pump** technology for this initial stage of the site development is to be discounted. Heat pumps require low flow temperatures to achieve commercially viable efficiencies, and so their application favours thermally efficient modern or wholly retrofitted properties, ideally with underfloor heating or over-sized wall hung radiators. Whilst a heat pump is not recommended for heating the existing property, it may be suitable at a later date if there is a new-build project on-site.

Biomass heating, on the other hand, offers the same flow temperatures as oil boilers enabling a like-for-like substitution. Fuel choice ranges from log wood, to woodchip to wood pellets with log wood requiring the most manual handling and wood pellet offering wholly automated fuel delivery to the boiler.

> Log wood: Logs at 20% moisture content (wet basis) have a calorific value of 4.1kWh/kg. 35 tonnes of 20% m.c. wood would be required to heat the main house alone. In terms of freshly felled wood (50% m.c.) this equates to 52 tonnes. The required forestry area required to service this demand from forestry residues would be 34 acres. This is based on a more commercially planted dense forestry resource. In the case of Greenhaugh the less dense woodland would not be able to sustainably provide the required fuel from forestry residues alone i.e. with this rate of wood extraction the woodland would be depleted with overall tree loss over time, unless felled trees were replanted as part of an active forestry operation. Additionally the manual labour to fell, stack for drying, move to fuel store and load daily would be onerous and beyond practical for a site of this nature (i.e. with no agricultural plant machinery and labour to hand). For this reason log wood is not recommended to fuel the main house and outbuildings.

Log wood may however be suitable for fuelling local space heating in small wood stoves within Meditation Huts, which may at a later date be placed within the woodland.

Wood-chip: Wood-chip is a bulkier form of Biomass to manage than wood pellet, and whilst cheaper (3.2p vs 4.6p/kWh) requires more expensive and robust fuel delivery augurs to automate fuel delivery to the boiler. Site storage of the wood chip requires, in addition to the boiler fuel store, a large bulk fuel store and potentially an additional drying fuel store. Telescopic handlers or similar plant machinery are required to move the fuel between stores. Generally commercial viability, due to the CAPEX required to install such systems, starts from a 200kW rating upwards. For these reasons wood-chip fuelled biomass is not advised for this site.

Wood-pellet: Wood pellet boilers offer the most automated Biomass heating option with a good record of substitution for oil boilers in houses of this size and age. Wood pellets are best delivered to site by specialist pneumatic lorries and 'blown' into fuel stores directly, with short distances from lorry to store favoured to ensure low-dust levels. The fuel is then automatically delivered by vacuum hoses to the boiler hopper (generally once a day for a 5-10 minute fill-up of the hopper). The fuel is then delivered via internal augur to the combustion chamber producing heat which is then typically stored in a large buffer cylinder or accumulator. District heat mains can then supply heat on demand with individual time setting and temperature set-points for each of multiple locations in need of space heating. The use of closed-cell insulated district heat main (eg Calpex) is advisable to ensure low heat loss within the heat main which is typically buried in trenches of 1000mm depth. For older properties with potential legacy issues within their existing radiator systems the heat supplied can be 'handed over' via Heat Interface Units (HIUs) which are highly efficient heat exchangers, thus hydraulically separating the primary and secondary sides of the heating system.

Within many protocols for carbon accounting, wood Biomass is seen as carbon neutral, forming part of the current natural carbon cycle. This is in direct contrast to fossil fuels which, when burnt, release long-term sequestered carbon.

In reality there are carbon costs related to the felling, processing and transport of wood pellets, however these are very small when compared to fossil fuels. Including processing and transport, wood pellets have a carbon intensity of 0.011-0.025 $kgCO_2$/kWh compared with oil at 0.35 $kgCO_2$/kWh. (http://www.woodpelletsupplies.com/content/wood-pellet-sustainability).

RHI - The Renewable Heat Incentive

The Renewable Heat Incentive is the government renewable technology scheme which pays the property owner for renewable heat generated at the property for space and water heating.

As a charity, 'Land of Joy' qualifies for the non-domestic heat incentive which runs for 20 years with payment fixed at the tariff level at the point of entry to the scheme and indexed to the Retail Price Index. The current tariff for non-domestic RHI is set at 8.6p/kWh for the first 1314 full capacity run hours and at 2.2p/kWh for heat generated thereafter. It is expected to degress (lower) over this year (there are degression points every 3 months). Under the current tariff a 100kW system will be paid at 8.6p for the first 131,400Kwh and at 2.2p for each kWh produced thereafter. A typical property with normal domestic occupancy profile will typically run the boiler for the equivalent of 2,000 - 2,400 full capacity run hours.

The non-domestic scheme will typically pay back the approximate £80-100k investment in 5-6 years, with further RHI income in the region of £13k per year thereafter. The fuel costs of the biomass are currently 75% that of oil. This fuel saving is expected to increase over time as the inflation trajectories of biomass and oil are 3% and 6% respectively based on the trends over the last twenty years for each fuel.

In Greenhaugh Hall's case it may be attractive to size the biomass scheme with sufficient capacity such that it can, in Phase 1, solely heat the main house and cottage, and in Phase 2 supply the additional heat to the converted outbuildings to be used for accommodation. As long as the boiler size from the original RHI installation is not increased the tariff levels for the second phase will be fixed at the original entry tariff to the scheme. In this way, subject to funding, a Biomass scheme could lock-on to the current favourable tariff rates if installed this year and 'future-proof' the heat supply to the conversion of the outbuildings to accommodation at a later date.

It should be noted that for charities VAT is chargeable on Renewable Heat Installations at 20% for administrative non-residential buildings and at 5% for buildings with predominantly residential use.

Possible location of the Greenhaugh Biomass scheme plant room

The plant room location is at this stage to be determined. The location will need to take into account the best accommodation configuration, whilst at the same time safeguarding the efficiency of the biomass scheme. This efficiency will, for example, be optimised by keeping the lengths of district heat main runs as short as possible (and by association the parasitic losses from electrical consumption of circuit pumps and heat loss along the heat main). It is worth noting that due to the presence of trees around much of the site, a high flue is likely to be required to ensure flue gases are carried away from the accommodation area.

One potential solution is shown below in which the plant room is sited in an existing stable block. Under this option, the prevailing SW winds will tend to disperse flue gases away from the main accommodation area:

An alternative solution may be to install an Energy Cabin (a pre-configured plant room within a container which can be clad in sympathetic material). This can be craned into position on a prepared concrete slab, subject to the constraint of crane vehicle access.

C. CHOOSING THE OPTIMUM RENEWABLE ELECTRICITY GENERATION SOLUTION

Some initial consideration has been given to electricity generation on site from Hydro and from Wind. Whilst these technologies have been discounted in the short-term they may merit further investigation in the mid to long term:

<u>Hydro</u>

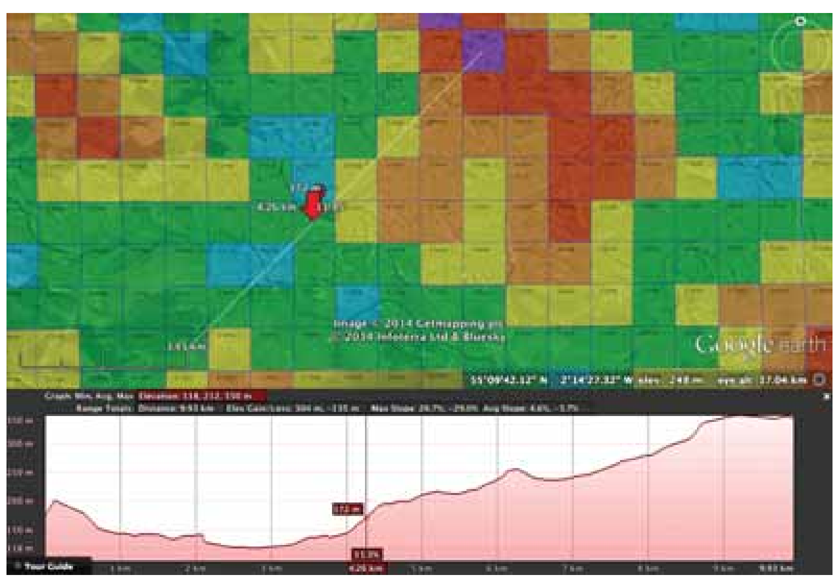
Water from higher ground flows via several small streams from east to west across the site, with an overall drop of 50m, into the Greenhaugh Burn which flows from North to South on the western boundary. The resource available for a Micro-Hydro scheme relies on the Static head (height of the fall) and the flow (litres/sec).

The flow profile over the course of the year will depend on precipitation over the upland catchment area, as well as Geology and the transpiration/evaporation characteristics of the land. This flow is difficult to predict with a desktop survey and given the considerable costs of installing a micro-hydro scheme, a year-long datalogging study of the flow characteristic would be advised to establish an annual profile. Further consideration should be given to an overflow from a lake on higher ground from which some of the water flowing across the Greenhaugh site is delivered (according to the previous owner who referred to this arrangement on the site visit). The security of this supply should be investigated, with the potential negative scenario in mind of the flow of water being either reduced by the owners of this lake in drier periods or diverted for some other use.

<u>Wind</u>

As with Hydro schemes, wind sites require a confident assessment of the resource available over a whole year. Annual Mean Wind speeds (AMWS) will determine, for the most part, the generation potential of the site. Given that the power generation from a turbine is proportional to the cube of the wind speed, a difference of just 1m/s in wind speed can separate a commercially successful project from a financial failure.

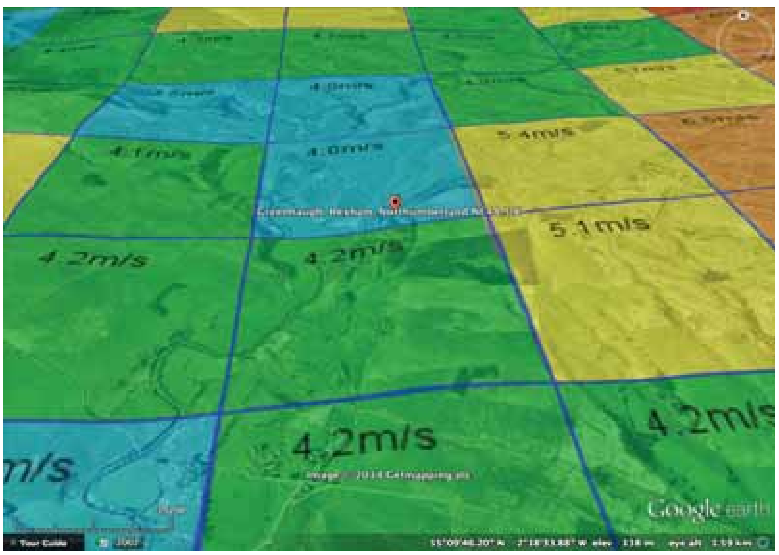
In this map (right), taken from the NOABL wind database, the Greenhaugh site is plotted within the elevation profile in the direction of the prevailing SW wind over 10km.



Colour coded 1km squares show rising wind speed at 10m hub height in the order of Blue, Green, Yellow, Orange, Red and Purple. The siting of Greenhaugh at 175m can be seen halfway over the rising elevation to 350m.

The wind resource at 10m hub height at a line extending North East of Greenhaugh shows an improving AMWS from 4.2m/s at Greenhaugh up to 8.2m/s just 5km away. An 8.2m/s AMWS would be very attractive and a seriously good commercial opportunity. The indicated AMWS for the Greenhaugh site paints a more uncertain picture.

At 4.2m/s the Greenhaugh site estimated AMWS is possibly viable, but is close to a borderline value for a commercially successful wind turbine project. It should be noted that NOABL gives a good first-stop indication of likely wind speeds, but that each 1km square represents the approximate average wind speed over the area. In a hilly site such as this there may be significant local variance. The Greenhaugh house is shown in the map below with the red marker. A suitable location for a turbine would most probably be in the open pastureland to the south of the site, bordered by the public road.



The site terrain in this instance would be classed as complex, placing further doubt on the reliance of NOABL for an indicative AMWS. Should further enquiry be of interest to establish more fully the site potential, then it would be advisable to commission a Virtual Met Mast report from the Met Office. This models the site using computational fluid dynamics with interpolated data from nearby weather stations to yield a more secure assessment of the wind resource. Such a report would cost in the region of £2,000.

Solar PV

In the open pasture to the south of the Greenhaugh Manor, the lower section of the field slopes downwards towards the South offering an attractive location for ground mounted solar with a 75m trenched cable run to the three-phase supply at the house. In the map to the right a 300m^2 area is shown (in red) which would accommodate a 12.5kW ground mounted solar PV array (numbering 50 PV modules). The trenched cable is designated by the yellow line.

A rough indication on pricing for a fully commissioned system including trenching would be just under £20,000. On this site the anticipated annual generation for this system would be 11,325kWh which would be close to a 100% offset of the electricity used on site over the source of a year.

Assuming a natural misfit between generation profile and consumption profile (in the winter months the array will not be generating in the dark when lights are on), a conservative assumption is of a 50% reduction in consumed grid-electricity by consumption of site-generated electricity. On this basis, and with current payback under the government Feed-in-tariff (FiT) scheme at 13.03p/kWh generated and 4.77p/kWh exported, the payback period would be 7 years and six months.

The scheme would continue to generate income to the net benefit of approximately £45,000 over the full twenty years of the FiT scheme.

D. IN CONCLUSION

Greenhaugh Hall and its surrounding land offers a diverse and sustainable series of choices for the employment of renewable energy generation technologies. In terms of carbon emissions the heat demand at the site will outweigh the electrical load by a factor approximately 8.

In consequence the greatest impact on sustainability will be to install a Biomass district heating scheme with the strategy of future-proofing further demand as outbuildings are converted for residential use, by sizing the boiler scheme to be capable of delivering to this extra demand. A 100kW scheme would cost in the region of £80-100k and payback over approximately 5-6 years with a guaranteed income stream up to year 20.

Electrical consumption on site could be offset 100% with the installation of a 12.5kW ground mounted array. Costing in the region of £20k this would payback in 7.5 years, assuming a 50% reduction in grid electricity consumption due to on-site generated electricity being used.

The Land of Joy may see investment in these technologies not only as a way to secure the sustainable operation of the site but also as a pathway to financial resilience over the 20 year period of the schemes.