Initial Carbon Investigation

For the

Lammas Project

The proposed Community Hub building

November 2009

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With assistance from Nick Swallow

Intro

This report represents an attempt to quantity the carbon impact of the ecovillage development of 9 self-build eco-smallholdings at Glandwr, North Pembrokeshire known as Lammas. The project was recently (August 2009) the first to gain prospective planning permission under Pembrokeshire innovative Policy 52, Low Impact Development.

This report has three aims:

- To give an overview of the carbon impacts associated with the development for educational purposes – this report to be published on the internet.
- To provide data for a funding application to the Low Carbon Community Challenge for capital funding for the project's Community Hub – a centre for the promotion, research and education of the potential for low-impact development to play a key role in society's transition toward sustainability
- To provide baseline data for further research projects in partnership with Science Shop Wales.

This investigation is divided into two parts: The first section examines the lifestyle impacts of the proposal. The project has recruited 9 families from different backgrounds from across the UK. The residents have re-designed their lifestyles using permaculture design techniques and are planning to substantially meet their household needs directly from the land. Some of the families are already living on the land in temporary accommodation whilst others are currently preparing to move.

The second section considers the land-use impacts of the proposal. The land for the development was purchased in January 2009 and consists of approximately 25 hectares of pasture (previously used to rear sheep) and approximately 6 hectares of mixed woodland. There were previously no dwellings or structures on the proposed land. The project is proposing a network of diverse holdings serviced by a sustainable infrastructure network.

The field of quantifying carbon impacts is, due to the wide variation in individual circumstances, somewhat generalised. This report is no exception. Whilst every effort has been made to be accurate with data, the calculations herein are used to provide estimates of carbon levels rather than precise statistics.

Carbon Impacts of Lifestyle

A survey was conducted in which the carbon impacts of the nine families involved with the Lammas were evaluated before they became involved with the project (table 1) and after their new homes have been constructed (table 2).

The carbon emissions of the households in their previous lifestyles averaged at 15.2 tonnes CO2 per year. As can be seen from the table, this encompasses a wide range of lifestyles. Plot 6 had the biggest CO2 footprint at 26.2 tonnes CO2 (largely due to high travel distances related to work) and plot 3 had the smallest at 9.9 tonnes (assisted by the use of biodiesel in their car). It was considered impractical to attempt to quantify the carbon impacts of lifestyle at the present moment because many of the residents are in the process of moving house and changing lifestyle.

The carbon emissions of the households in their proposed lifestyles averaged at 3.5 tonnes CO2 per year. In the Lammas project all household fuel and electricity are sourced directly from the land using renewables. Furthermore the households are growing the majority of their own food and are travelling less – their primary places of work being now at home.

Table 1: Estimated household CO2 production for Lammas residents in 2007/08

House-hold	Original fuel-heating source	Quantity used per annum	Household fuel Tonne CO2	Original electricity source	Quantity used per annum	Electricity Tonne CO2	Private - travel fuel	Quantity used per annum	Travel (tonnes CO2)	Food (tonnes CO2)	Bags of rubbish (and recycling)	Rubbish CO2 (tonnes CO2)	Work/ Education (tonnes CO2)	Total CO2
1	Gas and wood	12,000 kwh 2 tonnes wood	2.2	National Grid	4300 kwh	2.3	petrol	2000 litres	4.6	3.0	52 (69)	1.7	1.5	**15.1**
2	Gas	11,200 kwh	2.1	Good energy (renewably sourced)	2180kwh £262	0	petrol	207 gallons 942 litres	2.2	6.2	104 (104)	3.1	2.5	**16.1**
3	Gas	15,000 kWh	2.9	National Grid	3500kWh	1.9	biodiesel	310 litres	0	3.0	26 (52)	1.6	0.5	**9.9**
4	Oil central heating	17,000 kWh	4.3	SWALEC	3800 kWh	2.0	petrol	13,000 miles 1300 litres	3.0	4.0	69 (69)	2.1	1.0	**16.4**
5	(Gas)	16,000 kWh	3.0	National Grid	3880 kWh	2.1	petrol	1375 litres	3.2	1.4	26 (26)	0.8	0.5	**11.0**
6	Oil central heating	1700 litres 17,460 kWh	4.4	SWALEC	£470 3920 kWh	2.1	diesel	£4400 4000 litres	10.7	4.8	104 (104)	2.2	2.0	**26.2**
7	Oil central heating	3090 litres 31,734 kWh	7.9	Good energy (renewably sourced)	£340 2830 kWh	0	diesel	£2600 2364 litres	6.3	2.8	52 (69)	1.7	1.0	**19.7**
8	Oil plus wood	1330 litres 13,659 kWh	3.4	Ecotricity (50% renewable)	£600 4800 kWh	1.25	diesel	1800 litres	4.8	3.5	52 (69)	1.7	1.5	**12.6**
9	(Gas)	8,000 kWh	1.5	National Grid	3880 kWh	2.1	petrol	1000 litres	2.3	2.2	40 (20)	1.0	1.0	**10.1**

Table 2: Estimated projected household CO2 production for Lammas residents in 2010/11

House-hold	fuel- heating source	electricity source	Private - travel fuel	Future private travel fuel estimate	**Travel (tonnes CO2)**	**Food (tonnes CO2)**	**Bags of rubbish (and recycling)**	**Rubbish CO2 - Projected (Tonne CO2)**	**Work/ Education – Projected (Tonne CO2)**	**Total, Tonnes CO2**
1	Miscanthus/ SRC willow	Hydro/ PV	petrol	1000 litres	2.3	0.9	26 (26)	0.8	0.75	**4.8**
2	Miscanthus/ SRC willow	Hydro/ PV	petrol	470 litres	1.1	1.5	26 (26)	0.8	1.5	**4.4**
3	Miscanthus/ SRC willow	Hydro/ PV	biodiesel	930 litres	0	1.2	26 (26)	0.8	1.0	**3.0**
4	Miscanthus/ SRC willow	Hydro/ PV	petrol	650 litres	1.5	1.2	26 (26)	0.8	0.5	**4.0**
5	SRC willow	Hydro/ PV	petrol	688 litres	1.6	0.3	26 (26)	0.8	0.25	**3.0**
6	SRC willow	Hydro/ PV	biodiesel	£2200 2000 litres	0	1.2	26 (26)	0.8	0.75	**2.8**
7	SRC willow	Hydro/ PV/ wind turbine	biodiesel	£1040 945 litres	0	1.2	26 (26)	0.8	1.0	**3.0**
8	SRC willow	Hydro/ PV	biodiesel	800 litres	0	1.5	26 (26)	0.8	1.5	**3.8**
9	SRC willow	Hydro/ PV	petrol	688 litres	1.6	0.6	26 (26)	0.8	0.25	**3.3**

NOTES ON TABLE 1:

- *Food CO2: On average 1.4 tonnes of CO2 is generated in food production per person, per year in the UK. For vegetarians an average of 0.9 tonnes per person is used. For people who really make an effort to buy local food or grow their own, a figure of 0.6 tonnes per person is used.*
- *Rubbish CO2: For every large bag of rubbish an equivalent 0.02 tonnes of CO2 is produced in its manufacture, transport and methane generation. Only 0.01 tonnes is produced for the same quantity of recycled waste.*
- *The gas calculation is based on a conversion factor of 0.19 to work out how much CO2 is produced per KWh of gas used.*
- *The heating oil calculation is based on a conversion factor of 0.25 to work out how much CO_2 is produced per KWh.*
- *The electricity calculation is based on a conversion factor of 0.53 to work out how much CO_2 is produced per kWh of electricity used.*
- *Travel: calculating the amount of CO_2 in kg by multiplying litres by 2.31 for petrol and 2.63 for diesel.*

NOTES ON TABLE 2:

- *Food CO2: Given that households will be growing approximately 75% of their own food, and purchasing the remainder locally this is estimated at 0.3 tonnes of CO2 per person.*
- *The biodiesel is considered as having no net emission, being made locally from recycled chip fat.*

Where possible figures were sourced from 'The Carbon Trust'.

Carbon Impacts of Land-Use

Compiled with support from Nick Swallow, MSc (Architecture: Advanced Environmental and Energy Studies)

(Note: 1Mg=1 tonne, 1Tg=1 million tonnes, 1 tonne Carbon is the equivalent of 3.65 tonnes CO2)

It is established knowledge that land-use has a great influence on climate, probably exceeding the effect of greenhouse gases (GHG) emitted from the combustion of fossil fuels. The way we currently use the land not only produces the greenhouse gases CO2, N2O and CH4 from soils, livestock and fertiliser use (the effect of fossil energy to power our farming is very small compared to these), but is influential on the climate by altering transpiration and hence the amount of water vapour in the atmosphere, and by altering the reflectivity, and hence the capacity to absorb or reflect heat, of vast areas of the globe.
The effect of agriculture, whether of a type that is a major GHG emitter or not, in displacing major carbon (C) sinks such as forests and fens is of great significance.

Grassland accumulates C. The rates at which this happens vary greatly, and have been reported as being between 0.1 Mg and 2Mg ha^{-1} yr^{-1}, with the highest rates being in new grassland of low fertility and lowest rates reported in intensively managed grassland[1].
So we see that in this land-use type there is a trade-off to be had: high productivity and high fertility will give us good yields but less C sequestration and vice-versa.
In a traditional (grass/arable) rotation C will accumulate in the years in which the land is in grass and be lost in the years of cropping.
In permanent pasture there is (widely claimed) a gradual build-up of soil C, although once a significant soil organic C reserve is established the accumulation rate will be slow or equilibrium will be reached.
In continuous arable cropping with tillage there is a decline in C to a very low level if mitigation measures are not adopted. This loss can be mitigated by the adoption of minimum tillage techniques.

Woodland also accumulates C in the living trees as it grows.
A growing forest will accumulate C at 2 to 5 Mg $ha^{-1}yr^{-1}$ until maturity or first harvest.
UK forests are accumulating C at a rate of 4Tg yr^{-1} .This is approximately 2Mg $ha^{-1}yr^{-1}$. This rate is fairly high and is because much of our woodland is young and is still growing.[2]

Ruminant livestock are responsible for a very significant proportion of the world's GHG emissions because they produce methane from enteric fermentation. Emissions per sheep[3] are in the region of 5 to 7 kg CH_4 yr^{-1}, equivalent to 110 to 154 kg CO_2, or 30.05 to 42.08 kg C. a typical stocking rate for land like that at Pont-y-Gafel of 10 sheep per hectare could therefore reasonably be estimated to be producing methane equivalent to 360kg C $ha^{-1}yr^{-1}$. There will also be a nitrous oxide output. It would be reasonable on the land in question to consider this as equivalent to about 200kg C $ha^{-1}yr^{-1}$.

So the grazing by sheep of the land in question was emitting (C equivalent) in the region of 560kg C $ha^{-1}yr^{-1}$, or using Mg as above, 0.56Mg.

It is unlikely that any land management regime will have an infinite capacity to sequester C. C will accumulate in the biomass and soil until a stable state is reached when off-takes by harvesting or natural decay are equal to accumulation rates.
If we seek to sequester atmospheric C we can constructively adopt practices such as forestry or agroforestry on land that initially has a low amount of C in its soil and biomass. An ideal C sequestration scheme would be forestry on land that has been in continuous arable production for many years. But this C accumulation might be obtained at a cost in terms of yield forgone and in practice some sort of "halfway house" such as agroforestry or orchards can produce benefits in C sequestration and also produce worthwhile food outputs.

To sum up good land use in the context of climate change very briefly:
CH_4 and N_2O emissions from the livestock sector need to be reduced, current soil C stocks preserved and increased where depleted (i.e. reduce or eliminate tillage) and new biomass sinks (forests) need to be established.

Soil
If starting from a degraded arable situation typical of many soils that have been under continuous cropping for a generation these values apply[4]:

Table 3: Carbon Accumulation rates

Conversion to…	Carbon accumulation rate, Mg C $ha^{-1}yr^{-1}$
Forest	0.338* (Post & Kwon, 2000)
Grassland	0.332 (" ")
no tillage	0.57 (West & Post, 2002)
enhanced rotation complexity	0.2 (" ")

SOC accumulation continues over 5-20 years until a new equilibrium is achieved. Hence the rate of carbon sequestration peaks in the first 5-10 years and subsequently declines to zero.
*Additional to this value needs to be added the accumulation of C in living biomass in the forest of 2 to 5 Mg $ha^{-1}yr^{-1}$ which continues until maturity or first harvest[5]. In agricultural operations there is normally no net annual living biomass accumulation

It should be remembered that in the UK carbon inventory some 90TgC is to be found in forest biomass and an estimated 20TgC in other plants, wild and cultivated, whilst the amount of C in mineral soils is very much greater at 3000Tg and a further 3000Tg is to be found in peat soils.
It follows that whilst conservation and addition to biomass C is important, the conservation and enhancement of soil C stocks is of greater importance given the large quantities involved.

Caution needs to be exercised when reading material an this matter as many of those involved have commercial axes to grind or a strong urge to find justifications for what is traditional or dear to them and therefore, in their eyes natural and good. A case in point is the book by Graham Harvey "*The Carbon Fields*", which according to Charles Clover (http://www.timesonline.co.uk/tol/comment/columnists/guest_contributors/article6898068.ece) tells us that ruminant grazing of permanent pasture is good in climate change terms.
The pasture is a good C sink but the "good" of the pasture does not make ruminants any better – the answer put forward by some has been to keep the valuable grassland and use its production in anaerobic digesters to produce an energy output.
It should be remembered when reading documents from the Soil Association that it is an organisation dominated by livestock farmers.

Carbon levels on Pont y Gafel farm prior to Lammas project

The bulk of the area under consideration was permanent pasture grazed with sheep, typical of farms in the area. The pasture, being continuously grazed was relatively poor in terms of carbon sequestration. A figure of 0.2Mg $ha^{-1}yr^{-1}$ is used to reflect this.

The mature woodland (deciduous native) could be considered to have reached a natural equilibrium, with no net carbon movement.

The remaining woodland (coniferous plantation/ coppice) could be considered as sequestering C equivalent to forest reversion rates.

Table 4: Carbon levels on Pont y Gafel farm prior to Lammas project

	Area (Ha)	Carbon ratio (Mg C $ha^{-1}yr^{-1}$)	Carbon Sequestration rate (Mg C $ha^{-1}yr^{-1}$)
Grazed Pasture	25.4	0.2	5.1
Ruminants	25.4	0.56	-14.2

Mature Woodland	2.5	0	
Woodland plantation	3.6	2	7.2
Tracks	0.2	0	

On balance there would be a net emission of 1.9 tonnes C per year from the land in its former condition.
This is the equivalent of emitting 7 tonnes CO_2 per year.

Carbon levels for proposed Lammas project

In GHG terms the removal of the sheep from the land has been beneficial, removing an emission of 0.56Mg C per ha. The benefit from the removal of sheep would of course continue indefinitely.

Benefit will accrue on land that reverts to **forest**/ **woodland** of approximately 2 Mg C $ha^{-1}yr^{-1}$(see figures above)until maturity is reached (an estimated 50 years).
The woodland that was previously plantation will be managed as continuous cover forestry and would be expected to sequester carbon at the same rate. The mature woodland will be selectively thinned, stimulating growth in the woodland.

On some of the land **orchards/agroforestry** type operations are proposed. These will be beneficial as C accumulates in the trees/ shrubs and floor ecosystems/ pasture as they grow. As a rough guide a mature agroforestry or orchard plot could be considered as having 50Mg C tree biomass per ha (approx equivalent to 100Mg dry timber and a quarter of the amount of timber in a mature forest) which accumulates over a period of 30 years until equilibrium is reached. Areas of this type would be of benefit equivalent to 1.66Mg C per year.

Those areas under **perennial horticulture** or **soft fruit** would behave very similar to grassland, accumulating soil C as the biomass builds up, and then finding an equilibrium point. An estimate for the rate of carbon sequestration would be 1.3 Mg ha^{-1} yr^{-1}, being of a growth rate between grassland and mid-canopy shrubbery. This would continue for a period of approximately 8 years before approaching equilibrium.

Those areas still under **pasture** would accumulate C. Due to the change from intensive grazing to low density grazing patterns there would be a net benefit in the change. An estimate for the rate of carbon sequestration would be 1Mg ha^{-1} yr^{-1}, being grassland of low fertility over a period of approximately 5 years before levelling off. As soil C gradually builds the rate of sequestration will gradually decrease as the C levels incline towards equilibrium.

As the land was previously undisturbed pasture, there is a large reserve of C in the soil. Soils on this site probably contain approximately 200Mg C ha^{-1}. Where this is brought into **horticultural cultivation** there will be C loss through oxidation. Under annual tillage a loss of 3Mg C $ha^{-1}yr^{-1}$ could be expected[6]. As largely organic systems will be in use, residents will adopt systems that maintain a high soil C reserve because of its agricultural benefit in such a system. Carbon (an estimated 1.5 Mg C $ha^{-1}yr^{-1}$) will be returned to the soil in the form of compost, resulting in an estimated net loss of 1.5 Mg C $ha^{-1}yr^{-1}$

Under SRC for fuel in a closed system such as that proposed here there would be no net gain or loss for the carbon in the plant biomass. A minimal gain in soil C would be expected through leaf fall. This could be estimated at 0.5 Mg C $ha^{-1}yr^{-1}$

Table 5: Projected carbon levels on Pont y Gafel farm in 2012

Plot	Ha	Pasture (Ha)	Perennial Horticulture/ soft fruit (Ha)	Orchard/ Forest Garden (Ha)	Annual horticulture (Ha)	SRC Fuel (Ha)	Woodland	Livestock (number of sheep)	Tracks (Ha)
1	0.9	0.1	0.3	0.3	0.2				
2	0.9		0.5	0.1	0.3				
3	0.9	0.1	0.3	0.1	0.5				
4	0.9		0.1	0.5	0.3				
Shared	3		1	1		1			
	4.8	4.6							0.2
5	2.9	0.5	0.5	1.1	0.2	0.6			
6	2.4	0.7	0.4	0.5	0.2	0.5		10 (equivalent)	0.1
7	2.9	1.0	0.3	0.5	0.1	0.5	0.5	7	
8	2.2	0.4	0.3	0.7	0.2	0.6		3	
9	2.2	0.4	0.3	0.3	0.5	0.5	0.2		
Common	1.5	0.4		0.2		0.6			0.3
Woodland	6.1			2.5			3.6		
SUB TOTALS	**31.7**	**8.2**	**4**	**7.8**	**2.5**	**4.3**	**4.3**		**0.6**
Carbon gain rate		1Mg C $ha^{-1}yr^{-1}$	1.3 Mg C $ha^{-1}yr^{-1}$	1.7 Mg C $ha^{-1}yr^{-1}$ over 30 years	loss of 1.5 Mg C $ha^{-1}yr^{-1}$	0.5 Mg C $ha^{-1}yr^{-1}$	2 Mg C $ha^{-1}yr^{-1}$	Loss of 0.04Mg C $ha^{-1}yr^{-1}$ per sheep	nil
Carbon Sequestration (Mg $ha^{-1}yr^{-1}$)		8.2	5.2	13.3	-3.8	2.2	8.6	-0.8	

Net Result

It is estimated that there would be a net C sink of 32.9 tonnes per year as a result of the proposed land-use change in the Lammas project.

This is the equivalent of sequesting120 tonnes CO_2 per year

Other Considerations

There are two other factors that need to be considered in the carbon equations for the project. The first is trackways. The project has installed an estimated 4000 sqm of new trackway, and re-surfaced an estimated 2000 sqm of existing trackway. This has been achieved by quarrying stone from the land itself. The new trackway could be considered as completely losing its carbon soil reserve. Thus there would be an estimated one-off loss of 80 tonnes carbon. Re-surfacing the existing trackway would result in minimal carbon change. The quarries themselves, whilst emitting carbon in the short term (while the quarrying work was undertaken), would re-absorb their carbon as the soil/ new landscaping settles. Thus on balance the quarries themselves could be considered to neither emit nor sequester carbon. The use of the plant machinery on the site would also have a carbon impact, though this has been minimized by excluding road haulage from the process. No attempt is made to quantify this one-off carbon emission.

The second consideration is that of the new buildings being erected. The project is committed to using predominantly natural, local materials such as timber, straw, earth and stone. It plans to minimise the use of carbon-heavy materials such as cement, prefabricated building elements (such as brick) and insulation products, preferring instead to use materials that become positive carbon sinks, i.e. natural biomass elements (straw, timber, natural insulations etc). Where possible lime is used in place of cement and turf roofs would mitigate the soil carbon loss from the building sites to a degree.

Whilst it is beyond the remit of this study to conduct in-depth investigations into the carbon impacts of the construction processes, it would nonetheless be fair to suggest that the processes would be carbon neutral in that the carbon emissions as a result of building (glazing, plumbing, electrics) would be balanced by the carbon sinks involved in the heavy use of natural materials.

Conclusion

The field of carbon impacts is a relatively new one and the estimates used herein should be considered as guides rather than as hard data.
Nonetheless it is clear that the project will result in a considerable carbon gain.

The changes in lifestyles of the 9 families are sufficient to result in a massive drop in associated carbon emissions from an average of 15.2 tonnes CO_2 a year to 3.5 tonnes CO_2 a year.

Prior to the project the land under consideration was a net emitter of CO_2, releasing an estimated 7 tonnes per year.

The Lammas project will facilitate considerable soil and habitat transformation resulting in a net increase in carbon absorption rates. The projected carbon sequestration rates are estimated to be 120 tonnes CO_2 per year.

The project as a whole will act as a positive carbon sink, locking an estimated 88 tonnes of CO_2 a year in biomass and soil, whilst substantially providing for the needs of the families living there.

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