UNDERSTANDING THE IMPLICATIONS OF EMERGING SOIL CARBON LAND USE POLICIES FOR SURFACE MINING IN THE UNITED KINGDOM[1]

R. N. Humphries[2]

Abstract: The objective of this paper is to examine the implications and opportunities the emerging soil carbon and land use policies have for the surface mining industry.

Policies for the protection and sustainable use of natural soils in the UK have evolved from a simple land capability reinstatement focus of the later decades of the 20th Century to the current and new concepts of ecosystem service impacts for land use planning and assessment. Ecosystem services include the diverse role of soils as well as their adaptive response to climate change and mitigation, soil health and sustainable food production.

Of the various foci, soil carbon has been in the recent forefront of UK soil policy development, albeit it largely a matter of principle and aspiration in conserving the carbon stock in soils to avoid contributing further to the greenhouse gas inventory. However, at the present time, the evidence base is believed to be incomplete for full and reliable technical based guidance in the UK.

In respect of carbon rich organic soils there is clearer and specific guidance. This has arisen, not through surface mining, but largely through wind farm developments (for sustainable energy generation terms of carbon net benefit), and review of farming and forestation practices on carbon rich soils (that are typically associated with both the UK's windier uplands and low lying coastal land).

In terms of surface mining, the current guidance is limited to the exposure of former underground coal workings where a formula is given to offset the emission of methane through tree planting. However, it is anticipated, as general land use policy develops alongside a growing evidence base, that specific guidance and operational expectations will be forthcoming. This may be an opportunity for the mining industry to respond with its own innovative proposals.

Additional Key Words: organic soils, climate change, carbon sequestration, land use policy

---

[1] Paper presented at the 2012 National Meeting of the American Society of Mining and Reclamation, Tupelo, MS ***Sustainable Reclamation*** June 8 - 15, 2012. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

[2] Neil Humphries, Environmental Co-ordinator, Celtic Energy Ltd, Castlegate Business Park, Caerphilly, CF83 2AX, UK and Visiting Professor, National Soils Research Institute, University of Cranfield, Cranfield, MK43 0AL, UK.

Proceedings America Society of Mining and Reclamation, 2012 pp 269-285
DOI: 10.21000/JASMR12010269

http://dx.doi.org/10.21000/JASMR12010269

Introduction

Soil organic carbon (SOC), as soil organic matter (SOM), is widely accepted as a key 'soil indicator' of soil function in food and fibre, environmental interaction (including climate change), and heritage and landscape in the ecosystem service role of soils (National Soil Research Institute, 2005; European Union, 2006; Department of Environment, Food and Rural Affairs, 2009; Her Majesty's Government, 2009; UK National Ecosystem Assessment, 2011).

On the one hand, soil organic matter is a headline indicator of 'soil health' in the UK Government's "Sustainable Farming and Food Strategy" (Department of Environment, Food and Rural Affairs, 2006) because of its role as a growing medium, and on the other hand, it has a headline role in climate change and mitigation through release, sequestration and storage of carbon (e.g., Ostle et al, 2009).

In the UK it is believed that the largest surface terrestrial carbon stocks are in soils (Bradley et al, 2005), and are in the order of some 7.4 – 12.2 billion tonnes carbon (Dawson and Smith, 2007). The distribution of soil carbon stocks depend on climatic history (rainfall and temperature), landform and altitude, and land use history. Notably, Scotland has a disproportionate high carbon stock and accounts for about 70% of the UK total. This is because of the extensive occurrence of organic mineral soils and peats (Hodgson, 1974).

In habitat and land use terms, some 5 billion tonnes of the UK carbon stock is stored as partially decayed plant matter in upland blanket and lowland raised bogs (Ostle et al, 2009). Despite the high carbon content of their soils, on a real basis, the lowest carbon stocks are associated with the less extensive bracken and fen and swamp habitats. The more extensive arable and horticultural land, and improved grassland with their lower soil carbon content account for the next highest carbon stocks, although still substantially lower that the aggregate for the peat bogs.

The possibility that the UK's soil carbon stock could be an additional source of atmospheric carbon dioxide has led to the development of a plethora of land use based planning policies and aspirations (Table 1).

Table 1: UK and Use Planning Policies and Soil Carbon.

Policy	**Comment**
European Union, 2006. Thematic Strategy for Soils.	Directed at soil loss and compaction, not soil carbon per se.
Welsh Assembly Government, 2008. Welsh Soils Plan: Consultation Document.	Directed at farming practices and improving soil health.
Environment Agency, 2008. Agriculture and Land Use Strategy 2010-2013.	Directed at diffuse pollution control and reducing flooding risks.
Natural England, 2009. Land Use Strategy 2009-2013.	Increase in soil carbon storage is an aspiration.
Department of Environment, Food and Rural Affairs, 2009. Soil Strategy for England.	Directed at regulatory measures and incentives to protect soil carbon.
HM Government, 2009. UK Low Carbon Transition Plan 2009.	Recognition of importance of UK's soil carbon store and steps needed to enhance it.
Welsh Assembly Government, 2009a. Minerals Technical Advice Note 2: Coal.	Off-setting coal mine gas emissions.
Welsh Assembly Government, 2010. Climate Change Strategy for Wales.	Directed at educating agricultural industry about soil carbon management.
Scottish Government, 2010. Low Carbon Scotland.	Directed at protecting high carbon soils, reducing green house gas emissions from agriculture and sequestration by afforestation.
Welsh Government, 2011. Planning Policy Wales.	Directed at planning for climate change and protection of high quality agricultural land.
Scottish Government, 2011. Land Use Strategy for Scotland.	Directed at securing long term management of all land base carbon stores.

Whilst each of the policy statements is geared to different aspects of land use, whether it is climate change, food production or soil health as the drivers, the overall focus is to protect and increase the existing soil carbon stocks. On pulling the policies together, the following are the key planning led outcomes:

- Soil carbon storage and land development (including construction) is stated as now being a material consideration by the planning authorities and regulators, and government will progressively provide regulatory measures to protect soil carbon (Department of Environment, Food and Rural Affairs, 2009; Scottish Government, 2010). The UK Government will provide support to the planning authorities and is developing a 'tool-kit' for to assist planners to take soil carbon into account (Department of Environment, Food and Rural Affairs, 2009). More specifically, the Scottish Government has developed a 'calculator' whereby the loss of carbon through site development for wind-farm developments on upland blanket peatland can be calculated as a viability test for the low carbon energy generation (Nayak et al, 2008).

- The protection of existing peat bogs to maintain their high carbon stores is an essential requirement (Welsh Assembly Government, 2008; Department of Environment, Food and Rural Affairs, 2009; Scottish Government, 2010). The actions proposed include the cessation of peat extraction for fuel and horticulture, and the restoration of peatland hydrology.
- Agriculture has a key role in securing the management of land based carbon stores (Welsh Assembly Government, 2008; Scottish Government, 2010). This is particularly the case for arable based enterprises where soil carbon stocks are claimed to be continuing to decline (UK National Ecosystem Assessment, 2011). The restoration of arable land to low intensity permanent pasture is one action proposed. To stem soil carbon losses in Wales, the Welsh Government is introducing a bespoke agri-environmental scheme in 2012 to promote land farming practices that preserve soil carbon. The Welsh Assembly Government and the Scottish Government have jointly developed a model for estimating carbon emissions and sequestration in agricultural soils (Scottish Executive, 2007).
- Woodland creation on an extensive scale has a role in carbon sequestration and should be promoted. The Scottish Government (2010) in particular considers that there is particular scope in Scotland, although it accepts commercially this might not be viable. To promote investment the UK Government has set up the Woodland Carbon Code (Forestry Commission, 2011).
- There appears to be only one current mining related response to the carbon policies. This is woodland planting to off-set of mine gas emissions from exposed former underground coal workings during surface mining (Welsh Assembly Government, 2009a)

Whilst these policies are currently being enacted, there remains uncertainty as to whether soil carbon is declining or increasing in UK soils, what actually happens in different land management practices, and the actual carbon in UK soils (as the stocks below the 'plough layer' have not been accounted for in the inventories: Department of Environment, Food and Rural Affairs, 2009; Her Majesty's Government, 2009; Scottish Government, 2010; UK National Ecosystem Assessment, 2011).

Hence, it was decided in 2011 to begin to collect some baseline data from which an informed view could begin to be formed of implications of soil carbon based land use policies for the mining industry.

Soil Carbon Studies at Four Surface Mine Sites in South Wales Coalfield

Soil carbon data for mining schemes has been collected from time to time over the past 30-40 years, but the data is often difficult to obtain being located in in-house reports carried out for the regulators or the industry. In many cases it is likely that soil carbon was not measured as the main foci in past restoration schemes were the effects of mining on soil acidity, fertility, drainage and density.

A simple sampling program was devised which included the four former or active surface coal mine sites located in South Wales. These were Bryn Defaid and Parc Slip (both restored sites), and Selar North and Nant Helen (both operational sites). These encompassed a spectrum of land use, soil type and soil origin (Tables 2 and 3).

Table 2: Land Use Types at Study Sites.

Site	Lowland Pasture	Upland Grazing	Forestry Plantation	Landscape / Nature Conservation
Parc Slip	+			+
Selar North		+		
Nant Helen		+		+
Bryn Defaid			+	+

Five replicate soil samples were collected from each site, land use and history (i.e., undisturbed, restored, soil forming materials, mining waste) between September and October 2011. Samples were taken from the 5-10 cm layer (to avoid surface litter, faecal matter of grazing animals), air dried and sent for analysis at NRM's analytical laboratories at Bracknell, UK. There, the samples were oven dried at 105^{o}C, lightly ground and passed through a 2mm sieve. The soil organic carbon content (g C/100 g soil) of the prepared samples was determined using the Tinsley (1950) method. The mean and standard deviation in soil carbon content (on a weight for weight basis) is given in Table 4.

Table 3: Textures of Soils, Soil Forming Materials and Mine Wastes at Study Sites.

Site	Undisturbed Soils	Stored and Restored Soils	Directly Transferred Soils	Stored Soils	Soil Forming Material	Mine Waste
Parc Slip	sandy clay loam / organic silty loam	sandy clay loam / clay loam	sandy clay loam	N/A	N/A	N/A
Selar North	sandy clay loam	N/A	N/A	sandy clay loam / clay loam	sandy clay loam / clay loam	N/A
Nant Helen	amorphous peat	sandy clay / stony sandy clay	Amorphous peat	N/A	very stony sandy clay	N/A
Bryn Defaid	N/A	N/A	N/A	N/A	N/A	gritty sandy clay / heavy clay loam

Table 4: Sample Mean (Standard Deviation) of Soil Carbon Content (g C/100 g soil).

Sample Sites	**Undisturbed Pasture Soils**	**Stored and Restored Pasture Soils**	**Directly Transferred Soils**	**Stored Soils**	**Soil Forming Material**	**SFM and Restored**	**Mine Waste Colonisation / Forestry**
Parc Slip	9.558 (1.5471)	10.400 (2.3050)	6.402 (1.5605)	N/A	N/A	N/A	N/A
Selar North	7.462 (3.0976)	N/A	N/A	4.172 (0.4150)	2.366 (0.1853)	N/A	N/A
Nant Helen	32.080 (3.4114)	8.602 (2.4710)	41.560 (7.4088)	N/A	1.748 (0.5795)	4.324 (0.9326)	N/A
Bryn Defaid	N/A	N/A	N/A	N/A	N/A	N/A	4.688 (2.8776) / 2.554 (0.8106)

The data collected in this study are typical when compared with similar land uses and soil types in the UK (National Soil Resources Institute, 2005). The levels of 7.5-9.6 g Carbon /100 g soil in undisturbed pasture soils at Parc Slip (lowland) and Selar North (upland) are typical of levels 5.0-24.1 g C/100 g of soil in permanent pasture in similar situations. The peaty soils (32.1 g C/100 g soil) at Nant Helen corresponded with those typical (22.5-34.9 g C/100 g soil) of upland moorland.

The stripped, stored and replaced soils on the restored parts of the surface coal mines at Parc Slip (restored in the 1980s) and Nant Helen (the part restored in mid 1980s) have typical soil carbon levels (8.6-10.4 g C/100 g soil) of undisturbed pasture soils (5.0-24.1 g C/100 g soil). The directly transferred peat bog at Nant Helen retained typical soil carbon levels associated with undisturbed peat (41.6 and 36.6 g C/100 g soil respectively).

Whilst soil forming material (SFM - selected material from the overburden and overlying geologic materials and which have physical and chemical likeness to raw soils) have lower soil carbon levels (1.8-2.4 g C /100 g soil) than in developed soils per se (see undisturbed and stored soils in Table 3), the carbon levels increased when restored and managed as soil substitute. At Nant Helen (restored with SFM in the mid 1990s) soil carbon levels are in the order of 4.3 g C/100 g soil and typical of levels in maturing man-made soils (4.6 g C/100 g soil). However, the carbon levels at Nant Helen are significantly lower than that for the undisturbed organic moorland soils (which have developed large carbon stores over thousands of years) and which they replaced.

The naturally colonised and planted mine wastes at Bryn Defaid have similar carbon levels (2.9-4.7 g C/100 g soil) as cited as typical for man-made soils (4.6 g C/100 g soil), but notably lower than those achieved at the other restored sites.

Soil Carbon Policy Implications for Surface Mining

Currently, it is typical that there is no requirement of the planning process in the environmental impact assessment and consent conditions for mining operations having to measure and monitor soil carbon, or make provisions for the management of carbon stocks in soils before, during and after mining.

On first reflection it might be expected that the industry, and possibly the planning authorities and the regulators too, consider that the emergence of the soil carbon has little or no implications for mining proposals in the UK. Given that the policy statements and the supporting evidence are spread across several documents and issued by different authorities it is likely that these are considered separately and not as a whole. This makes it particularly difficult for practitioners to determine whether or not there are implications and what actions they should be taking.

Taking the baseline data collected for the four previously and currently consented surface coal mine sites in South Wales, two (Bryn Defaid and Selar North) apparently did not have peat or organic soils, and consequently soil carbon stocks would not have been a consideration in granting planning consent. The other two (Parc Slip and Nant Helen), on the other hand, had organic soils and deep peat respectively. For Parc Slip, it would have been anticipated that the emerging policies would not have prevented planning consent being granted, but would have required specific details for the storage and re-use of these soils with some restriction in post mining land use so that carbon stocks were maintained. This would have probably excluded productive agriculture and forestry. A proposal to mine Nant Helen with its area of deep peat could have been resisted on carbon storage grounds if an application was being made at the present time. Whilst the peatland did not cover the entire coal prospect, its supporting catchment probably did, consequently the application for the site would probably have been dismissed. There is some irony in this prospect, as the mine was consented before the soil carbon and climate change issues arose, and the peatland has been mined and the peatland restored showing that the occurrence of peatland need not necessarily preclude surface mining and the protection of soil carbon stores.

Taking the policy statements and background as a whole, it is evident there are likely potential as well as tangible implications, and there may be opportunities as well as constraints. With this as foresight, what now might be required of the industry and how the industry might be prepared is discussed below.

<u>Land Use Planning and Soil Carbon Stock</u>

It is evident from the recently developed land use policies (those elements which address climate change and maintain 'soil health') that the carbon stock in soils is likely to be a planning matter in future developments, including mining applications, and that a great amount of information will be required.

The Department of Environment, Food and Rural Affairs (2009) policy statement is not specific as to the carbon content that might trigger consideration and may embrace "all" (high and low carbon) soils (as is the intent of the Scottish Government Land Use Strategy, 2011). It is anticipated that the forthcoming Department of Environment, Food and Rural Affairs 'tool kit' may clarify this.

In terms of climate change matters, high carbon soils (peat, organic-mineral soils) will be of particular concern to the planners and regulators. Such high carbon soils will be encountered in many upland locations in the UK and also in lowland locations (typically coastal) with fens, marshes and raised bogs.

For 'soil health', the policies and development control are concerned with the issue of retention of sufficient carbon, as organic matter, in soils to maintain their functions and services to maintain soil fertility, water balances and quality structural coherence of soils. Low carbon soils are the more extensive in the UK in real terms, and the dominant types in the lowlands (particularly those under cultivation).

One outcome of the climate change and soil health elements of the soil carbon policies in planning applications and environmental impact assessments will be the specified need at the scoping stage to detect the presence of carbon rich soils in pre-development surveys and to measure soil carbon content in the soils. The objective will be to assess the risk of carbon loss from soils as a result of the development, and to identify and enact any necessary mitigation measures. It may be that measures to ensure soil carbon levels are maintained and incorporated as legally binding obligations in planning consents and post-development assessments at mine closure will be required to verify this.

Where the soils are of a particularly high carbon type it is likely that more detailed assessments will be required than in the case of low carbon soils, and might involve the use of such tools as the Scottish Government's 'carbon calculator' (Nayak et al, 2008) to determine the loss of carbon on disturbance. For mine development planning and high carbon soils this will need a better understanding of soil carbon fluxes and mining operations (soil stripping, storage, replacement, aftercare) and options than currently exists. However, it might be expected that a *tool kit* and *calculator* approach might be requested in environmental impact assessments for all soils, and particularly if a *carbon footprint* of the mining scheme is required (in which the soils will be a contributing element. Whilst carbon foot-printing of mining operations in the UK is not currently undertaken, it is in many overseas ventures where institutional finance is involved.

Given that there is a likelihood soil carbon will be considered in future schemes, the background to the policy formation suggests it might not be straight forward to convince the authorities and regulators; particularly as the 'precautionary principle' will be exercised in such matters. For example, it is unclear whether UK soil carbon stocks are increasing or decreasing. Certainly if they are decreasing, there will be greater insistence to demonstrate that the mining operation is not contributing to this. As a consequence old debates about soil storage and loss of organic matter might be re-ignited (Abdul-Kareem and McRae, 1984; Visser et al, 1984; Harris and Birch, 1989). In the absence of information to the contrary this may increase pressure for less storage and more direct placement of soils in the design of schemes which might inhibit the development of some prospects.

Similarly, the uncertainty of the effects of various land use management practices is likely to make it more difficult to convince the authorities and regulators about the benefits or benign nature of schemes and their after use. To overcome this, evidence will have to be collected either from existing knowledge or by means of monitoring and/or trials. All of which will take time to collect and will need the industry to have foresight and be proactive if it is not to inhibit some prospects.

Matters are made worse by the acknowledgement that soil carbon inventories are not well enough understood as they usually do not account for the carbon content in the entire soil and geologic profiles. In addition, the sampling of soil profiles for soil carbon, if undertaken at all, is often restricted to within the 'plough layer' (0-30 cm) or even a thinner section of the topsoil profile. Undoubtedly, soil carbon data will have to be collected for the entire profile. The implication is that the industry cannot rely on data from elsewhere and will be expected to undertake comprehensive and well planned surveys and sampling of its own, and carry the expense. The 2011 soil carbon survey described here for four mine sites in South Wales can only be seen as a starting point. Whilst it is indicating that broadly soil carbon levels in restored sites are within ranges that might be expected, it does not have the rigour to address the shortcomings of the general knowledge base about soil carbon and that more detail will be demanded by the overseeing authorities. This will include sampling of full soil profiles before- and after-mining, and possibly carbon fluxes in high carbon soils.

Protection of Peatland Soil Carbon Stock

The soil carbon and peat policies are directed at preserving their existing high carbon content by cessation of peat extraction and drainage (for conversion to forestry and agriculture), and increasing their carbon stock where 'peatland restoration' is possible (mainly by raising water tables and stemming drainage ditches).

Does this mean that sites with high carbon soils are to be barred from being developed or mined? On examination, in the absence of other overriding planning constraints such as biodiversity and protected sites (Her Majesty's Government, 1994; Office of the Deputy Prime Minister, 2005; Welsh Assembly Government, 2009b), the soil carbon policies do not prevent development of sites with high carbon per se.

For example, many wind farms have and are likely to be constructed on peat and organic soils in the windy upland and lowland situations, and planning consent is dependent on the carbon balance achieved. In the same circumstances, the same might apply to mineral developments. There, it would have to be demonstrated that soil carbon stocks can be maintained during mining and on restoration. This might be by implementing standard measures such as recharge trenches/'ring-mains' (as successfully used at the Avon Common sand and gravel site to stem the dewatering of surrounding peatlands) and flooded borrow pits (as successfully used to store peat without carbon loss before its reuse on restoration as at the Nant Helen surface coal mine site.

In the absence of other ecosystem service constraints, such as biodiversity or water resources, mining, in contrast to other developments, provides a unique opportunity to remove high carbon stocks from readily becoming atmospheric gases by burying them during the excavation and refilling process. This could be beneficial by creating new land uses.

For example, the burial of high carbon stocks could overcome the 'sterilisation' of productive land uses by the protective policy for high carbon soils. Such sites, after mining, could be released for a wider range of land uses at a future time when it is acknowledged there is increasing competition for usable land resources for agriculture and forestry (Scottish

Government, 2010). Sites without their high carbon soils might be particularly attractive for forestry and especially by the extensive planting of hard-wood tree species. Both agriculture and forestry uses on substitute mineral restored soils (possibly using some of peat in topsoil layer as a soil conditioner) is likely to be more productive than on the in situ peat and sequester higher levels of plant and soil carbon. Hence, in planning terms, both the burial of high carbon soils and the conversion to a lower carbon stock based land use with a higher potential for sequestration could seen by the planning authority to be positive environmental consequences of a mining application and contribute to its consent.

On the other hand, it could create an opportunity to create new and more vigorous carbon sequestration habitats such as wetlands (swamps and fens) which seem to have been the precursors of much of the World's coal deposits (Haszeldine, 1989). The logic being that the site before mining was predisposed to carbon accumulation due to climatic (cool temperatures and year-round high rainfall) in combination with topographical and drainage factors (Patrick and Humphries, 2003; Mead and Humphries, 2007). Reliance on conventional reclamation to achieve high levels of carbon storage may be unwise given that typically the accumulated carbon arose under very different climatic conditions in the UK's history during the Holocene Epoch. These conditions do not prevail now and it is predicted that conditions will become even less favourable with higher annual temperatures and seasonally lower rainfall. In this context, it is almost certain that much of the UK's soil carbon stock might be lost without there being an opportunity and finance to do much about it.

However, because of hard fought campaigns to protect peat bogs and landscapes from forestation and horticultural peat extraction, there is likely to be considerable resistance in many cases to a proposal to burying of peat as suggested. The long battles won by the conservation bodies will not willingly be refought.

In many cases resistance on eco-service and/or conservation grounds will be justified and will probably inhibit mining schemes. In others, especially where such limitations do not apply and where the land use is agriculture or forestry, a case to bury high carbon soils could be successful. To achieve this, there will have to be the attention to detail and careful consultation with planning authority, regulators and other stakeholders and prior to the development of proposals. Mining companies should expect to provide detailed plans and supporting evidence that the soil replacement schemes are deliverable and sustainable. Examples are likely to be requested, along with evidence of soil carbon sequestration and carbon balance such as those undertaken by Drozdowski et al., (2010) for the reforestation of oil sands in Canada.

There is probably considerable evidence already available in the UK from similar schemes undertaken in the 1980-1990s by British Coal when it was common practice to substitute organic soils and peat with inorganic material from lower soil/geologic horizons. However, many of these plantings suffered from poor soil handling practice and soil compaction, besides being planted with soft-wood timber rather than hard-wood species. It should be expected that some research and trials will be required to provide the evidence needed to satisfy the authorities and regulators.

Agricultural Management of Soil Carbon Stock

The intent of the policies relating to agriculture and soil carbon stocks is to promote good or farming practices that preserve and ideally increase soil carbon levels (Welsh Assembly Government, 2008; Department of Environment, Food and Rural Affairs, 2009; Scottish Government, 2010). There is often an aspiration to convert from arable to extensive permanent grassland enterprises. However, such aspirations are unlikely to be achieved because of the economic value of other crops.

In this context, mining could be beneficial as it has the potential to achieve both the good practice and crop conversion goals through an agreed after-use of sites, providing the vehicle to upgrade farm establishments and practices, and convert to other types of agricultural enterprises. To this end the mining industry will need to have detailed proposals and the supporting evidence to put before the planning authorities and regulators to convince them that its proposals are achievable, sustainable and deliverable in terms of delivering preservation or increase in carbon stocks in perpetuity. This may include matters of land ownership, covenants, and controlling ownership and management.

4 Conversion to Forestry and Soil Carbon Stock

The enhanced sequestration of carbon through the extensive planting of trees is seen as a particular goal of the policies, and especially in Scotland in their quest for a low carbon economy (Scottish Government, 2010). However, in the same way as for its aspirations and agriculture, it is accepted that this will be particularly difficult to achieve as forestry as a land-use is not economically competitive with other crops, and particularly on the higher quality soils of lowland areas.

Mining, as for agriculture, has the potential to overcome the otherwise economic constraint to conversion promote a forestry as a land use, and in land use planning and soil carbon sequestration terms would be highly beneficial. To this end the mining industry will need to have detailed proposals and the supporting evidence to put before the planning authorities and regulators to convince them that its proposals are achievable, sustainable and deliverable over the long term and in perpetuity. As for the benefits for agriculture, this will include matters of land ownership, covenants, finance, controlling ownership and management.

Conclusions

Contrary to the belief of some analysts, the recent adoption of soil carbon policies for land use in the UK could have profound implications for some mining schemes. As with most new policies there is a lag-period before their enactment in practice and the consequences being felt by developers. We are most certainly well into this period. Foresight by the mining industry will enable it to prepare its case by collecting the evidence required and innovative design of sustainable soil carbon schemes.

Whilst development regulations, such as soil carbon land use policies, are often seen in a negative manner by developers, there are opportunities for the mining industry whereby schemes can be both beneficial in achieving the policy goals and unlocking land for more productive land uses.

Acknowledgements

I am grateful to Celtic Energy Ltd for funding the study of their sites in South Wales, Paul Benyon (URS Infrastructure and Environment Ltd, UK) for kindly collecting the soil samples and to Natural Resource Management Ltd, Bracknell, UK for their advice on soil carbon analysis. The views expressed are solely those of the author and not necessarily those of Celtic Energy Ltd.

Literature Cited

Abdul-Kareem, A.W. and S. McRae. 1984. The effects on topsoil of long term storage. Plant and Soil, 76 (1-3), 357-363. http://dx.doi.org/10.1007/BF02205593.

Bradley, R.I., P. Milne, J. Bell, A. Lilly, C. Jordan, and A. Higgins. 2005. A soil carbon and land use data base for the United Kingdom. Soil Use and Management, 24, 363-369. http://dx.doi.org/10.1079/SUM2005351.

Dawson, J.J.C. and P. Smith. 2007. Carbon losses from soil and its consequences for land-use management. Science of the Total Environment 382, 2-3, 165-190. http://dx.doi.org/10.1016/j.scitotenv.2007.03.023.

Department of Environment, Food and Rural Affairs. 2006. Sustainable Farming and Food Strategy: Forward Look. London.

Department of Environment, Food and Rural Affairs. 2009. Safe Guarding Our Soils: Soil Strategy for England. London.

Drozdowski, B.L., T.M. Macyk, R.L Faught, and R.J. Vassov. 2010. Carbon storage I landscapes affected by oil sands mining in Alberta's northern boreal forest, Proceedings America Society of Mining and Reclamation, 2010 pp 228-247 http://dx.doi.org/10.21000/JASMR10010228

Environment Agency. 2008. Agriculture and Land Use Strategy 2010-2013. Reading.

Forest Commission. 2011. Woodland Carbon Code. London.

European Union, 2006. Thematic Strategy for Soil Protection. Brussels.

Harris, J.A. and P. Birch. 1989. Soil microbial activity in opencast coal mine restorations. Soil Use and Management, 5 (4), 155-160. http://dx.doi.org/10.1111/j.1475-2743.1989.tb00777.x0.

Haszeldine, R.S. 1989. Coal Reviewed: depositional controls, modern anologues and ancient climates. Geological Society (London), 41, 289-308.

Her Majesty's Government. 1994. Statutory Instrument 2716: Conservation (Natural Habitats and c) Regulations. HMSO, London.

Her Majesty's Government. 2009. The UK Low Carbon Transition Plan: National strategy for climate and energy. London.

Hodgson, J.M. 1974. Technical Monograph 5: Soil Survey Field Handbook. Soil Survey, Harpenden.

Meade, R. and R.N. Humphries, (Eds). 2007. Mineral Extraction and Wetland Creation. Natural England, Peterborough.

National Soil Research Institute. 2005. Project SP0546 - Soil Organic Matter as an indicator of Soil Health. Department of Environment, Food and Rural Affairs, London.

Natural England. 2009. Landuse Strategy 2009-2013. Peterborough.

Nayak, D.R., D. Miller, A. Nolan, P. Smith, and J. Smith. 2008. Calculating Carbon Savings from Wind Farms on Scottish Peat Lands – A New Approach. Scottish Government, Edinburgh.

Office of the Deputy Prime Minister. 2005. Planning Policy Statement 9: Biodiversity and Geological Conservation. HMSO, London.

Ostle, N.J., P.E. Levy, C.D. Evans, and P. Smith. 2009. UK land use and soil carbon sequestration. Land Use Policy, 26S, S274-S283. http://dx.doi.org/10.1016/j.landusepol.2009.08.006.

Patrick, C.K. and R.N. Humphries. 2003. Conceptual models underlying the restoration proposals for Bowness Common. pp 8-11. *In* R. Meade (ed), Proceedings of the Risley Moss Bog restoration Workshop, February 2003. English Nature, Peterborough.

Scottish Executive. 2007. ECOSSE: Estimating Carbon in Organic Soils – sequestration and emissions. Edinburgh.

Scottish Government. 2010. Low Carbon Scotland: The draft report on proposals and policies – A low carbon society. Edinburgh.

Scottish Government. 2011. Getting the Most From Our Land: A landuse strategy for Scotland – Action Plan. Edinburgh.

Tinsley, J. 1950. The determination of organic carbon in soils by dichromate mixture. Transactions of 4th International Congress Soil Science (Amsterdam), 1, 292-298.

UK National Ecosystem Assessment. 2011. The UK National Ecosystem Assessment: Synthesis of the Key Findings. UNEP-WCMC, Cambridge.

Visser, S., J. Fujikawa, C.L. Griffiths, and D. Parkinson. 1984. Effects of topsoil storage on microbial activity, primary production, and decomposition potential. Plant and Soil, 82, 41-50. http://dx.doi.org/10.1007/BF02220768.

Welsh Assembly Government. 2008. The Welsh Soils Action Plan: Consultation document. Cardiff.

Welsh Assembly Government. 2009a. Planning Policy for Wales: Minerals technical advice note 2 – Coal. Cardiff.

Welsh Assembly Government. 2009b. Planning Policy for Wales: Technical advice note 5 – Nature Conservation and Planning. Cardiff.

Welsh Assembly Government. 2010. Climate Change Strategy for Wales. Cardiff.

Welsh Government. 2011. Planning Policy for Wales. Cardiff.