OPPORTUNITIES FOR RENEWABLE TECHNOLOGIES AT QUARRY SITES

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Abstract

The quarrying industry consumes a significant amount of energy in its extraction, processing and distribution activities. This has financial and environmental costs, and potential exists to reduce both through the use of sustainable energy. One aspect of energy consumption of particular importance in the extractive industry is associated with pumping and dewatering activities and a water use audit can identify areas of potential savings. Energy schemes incorporated within the operational life of a quarry may be financially attractive and could also benefit the local community during site afteruse. Potential exists to off-set operators' global emissions against long-term reductions in carbon emissions for sites and their surrounding communities.

A case study looking at energy generation potential and carbon off-setting is presented based on data supplied for the Tarmac sand and gravel quarry at Scorton. Fossil fuels currently supply a specific energy use of 8.4 kWh/t (4000 MWh/yr) comprising both mains electricity and diesel for plant. Electricity requirements could be met through sustainable energy schemes including a hydroelectric barrier on the River Swale or a large (70m) wind turbine. Other technologies considered included photovoltaics, solar thermal, and heat pumps. Potential energy consumption associated with a range of site afteruses is presented. Government incentives have made long-term (>10 years) sustainable energy generation a potentially worthwhile investment.

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Introduction

The quarry and mineral industry has a role to play in contributing to the implementation of sustainability. Within the industry there is a firm commitment to leaving a lasting legacy for post-extraction sites and also emerging demands to meet performance targets for sustainability. Hafren Water has undertaken research, through the Minerals Industry Research Organisation, into opportunities for renewable energy generation during the life of the quarry and subsequent restoration (Ellis *et al*, 2008).

Quarries and mineral extraction sites present interesting locations for exploring sustainability issues. In particular, the following elements are pertinent:

Drivers for Renewable Technologies

The drivers for reductions in energy consumption and CO_2 emissions are many including economic and environmental costs, corporate image and climate change. For example;

- Tarmac has a commitment to reduce specific energy consumption (energy used per unit of production) by 15% by 2014, based on 2004 levels (Tarmac, 2010).
- Aggregate Industries has a target of 20% reduction of CO_2 per tonne from a 2008 baseline, to be achieved by 2012 (Aggregate Industries, 2011).
- Cemex has a commitment to reduce CO_2/m^3 emissions from production by 15% from 2008 levels by 2012 (Cemex, 2009).
- Hanson has made a commitment to increase the use of alternative fuels used in cement production to 70%, and in particular increase the use of biomass by 2012 (Hanson, 2009).

Energy costs and carbon offsetting

The quarrying industry consumes a significant amount of energy in extraction, processing and distribution activities. This has financial and environmental costs and potential exists to reduce both through the use of sustainable energy. Energy schemes incorporated within the operational life of a quarry may be financially beneficial and could also benefit the local community during site afteruse. Potential exists to offset operators' global emissions against long-term reductions in carbon emissions for sites and their surrounding communities.

Environmental resources:

Quarries are often located near watercourses with significant hydro-electricity generation potential. Mineral extraction often results in large waterbodies supported by groundwater and surface water inflows which store a considerable amount of thermal and potential energy (gravity flow). Solar and wind energy and biomass fuel are also potential options to be considered. A case study looking at energy generation potential and carbon offsetting was undertaken and is referenced herein, based on data supplied for the Tarmac sand and gravel quarry at Scorton, North Yorkshire.

Energy assessment and monitoring

As part of a site energy assessment it is essential to gather information on energy use and source at each stage of the cycle. The more detailed the data, the greater the possibilities for instituting energy efficiency measures and assessing the potential for renewable technologies. Basic monitoring of energy bills and fuel consumption can be augmented by more specific monitoring with greater temporal resolution.

Tarmac's energy consumption at Scorton was considered across the entire quarrying process from extraction, material handling and processing to delivery of the final product in terms of heat and power, which in combination provided the specific energy per unit of production. Energy consumption data for 2007 is presented in Table 1.

Source	MWh	CO_2 emissions (tonnes)
Electricity	1379	592
Diesel fuel	2668	787
Total production (tonnes): 480,699 Energy use per tonne (kWh/t): 8.4		

Table 1. *Scorton Quarry average energy consumption (2007)*

The specific energy use of 8.4kWh/t compares with an average of 8.3kWh/t in 2008 across all of Tarmac's sand and gravel sites (Tarmac, 2010) and the study is therefore considered to be representative. Consumption for other sectors is presented in Table 2 and by comparison asphalt production is an order of magnitude more energy intensive, averaging 98kWh/t during 2008 (Tarmac, 2010).

Sector (unit)	kWh/unit
Scorton case study	8.4
Sand and gravel (tonnes)	8.3
Crushed rock (tonnes)	9.7
Asphalt (tonnes)	98
Ready-mixed concrete (cubic metres)	4.1
Building products (tonnes)	16.5

Table 2. *Direct energy consumption per unit of production in 2008 (Tarmac, 2010).*

In the case of Scorton Quarry the majority of the energy use was through diesel for the mobile plant and electricity to power the mineral processing plant. There was little requirement for heat apart from the site offices. In contrast high temperature heat energy is much more significant for asphalt and cement production. The renewable technology implemented should match the energy type required.

Water Audit

One aspect of energy consumption of particular importance in the extractive industries is associated with pumping and dewatering activities (QPA, 2008).

Existing environmental management systems should provide records of basic information on site water use, but further detail will allow areas of inefficiency to be identified. Monitoring data for a site's water abstraction and discharge may already be collected as an Environment Agency requirement for an abstraction licence or discharge consent (now known as an Environmental Permit). The impending implementation of the transfer licence scheme, as part of the Water Act (HM Government, 2003) to control quarry dewatering, will increase monitoring requirements and it makes sense to consider water consumption and transfer in terms of both volume and energy.

Water usage should consider the water quality required to be fit for purpose as each stage of water treatment and quality improvement has energy, CO_2 emissions and cost implications. For example, operators should investigate potential groundwater or surface water supplies in place of high quality (and expensive) mains water for such activities as wheel washing. If required, basic treatment of raw groundwater or surface water may be a cost-effective alternative to the mains supply.

Dewatering operations at quarries working sub- water table have often evolved over many years and across different phases of work. What was originally efficient may no longer be the case, and a review of pipework and pump efficiency could lead to significant energy, CO_2 emissions and cost savings. The method of working may be refined to incorporate low permeability barriers, either natural *in-situ* strata (e.g. clay horizons) or placed material (e.g. overburden, silt from mineral washing). Some workings may allow gravity drainage. During periods of economic downturn, quarries may be mothballed and a decision as to whether to continue dewatering or not is required. In the case of the latter the potential impact of water level rise on such issues as slope stability and restoration schemes should be considered.

Initial drawdown may have taken place over a long period and the time taken to reduce water levels prior to recommencing operations at an acceptable discharge rate may be considerable. In such instances the potential reduction in operating costs by the termination of pumping must be weighed against additional pump capacity requirements and increased discharge arrangements with the Environment Agency. Each case is site-specific but, for example, continuous pumping at a rate of 20 l/s throughout the year with an electric submersible pump would cost in the region of £17,500 (assuming 40m head loss, pump efficiency 40%, electricity 10p/kWh).

Clean Energy Technologies

Clean energy technologies consist of energy efficient and Renewable Energy Technologies (RETs). Both of these reduce the use of energy from "conventional" sources (e.g. fossil fuels). A renewable energy resource is one where its use does not affect its future availability and is beneficial for a number of reasons: Environmental - reduced carbon emissions, pollution and transport requirements; Economic - low lifecycle costs, offset rising energy prices and the risk of price shocks. RETs are beneficial for social reasons as they often utilise more labour than in conventional technologies and are more dispersed, dilute energy resources. The resources are local and the money spent stays within the local economy.

Several barriers exist to the implementation of renewable technologies including the high initial capital expenditure. Whilst in the long-term the return on investment may be significant, many companies consider much shorter timescales, with rapid payback required. Renewable technologies often have a higher level of complexity prior to implementation than conventional systems. Detailed feasibility assessments are often required to characterise the available resource (e.g. groundwater, surface water, wind) and engineering designs are required. Permitting may also be an issue, with planning permission potentially more difficult to obtain and negotiations required with the Environment Agency.

A selection of the most common renewable electricity generation technologies are wind energy system, hydro energy system, photovoltaic system and combined heat and power plant (CHP). Common renewable heating and cooling technologies include biomass heating systems, solar air heating systems, passive solar heating systems, ground source heat pumps, ventilation heat recovery, efficient refrigeration systems and CHP technologies.

Quarry CO_2 Emissions

The total CO_2 emissions from Scorton Quarry have been calculated as equivalent to 1,239 tonnes of CO_2 per year on the basis of records of fuel (64%) and electricity (46%) consumption. Emissions via power from the national grid is at an assumed rate of 0.429 kg/kWh, representing a UK standard mix of power station fuel sources and efficiencies, plus transmission losses via the grid. Table 3 shows a range of alternative metrics with which to put the quarry emissions into perspective. The 1,239 tonnes of CO_2 per year generated at Scorton Quarry could be offset against the items and activities shown Table 3.

Value	Criteria
1239	Tonnes CO_2 annual emission from Scorton Quarry
252	Cars and light trucks
1239	People reducing energy use by 20%
426	Hectares of carbon-absorbing forest
417	Tonnes of waste recycled

Table 3. *Scorton Quarry emissions metrics (calculated using RETScreen software).*

Land use scenarios

A number of land use scenarios were considered for Scorton Quarry, bringing together the elements of sustainable development and alternative technologies combined with national and local sustainability requirements. The purpose of the scenarios was firstly to respond to requirements for economic development, affordable housing and diversification (both locally and nationally) and secondly to consider the relative economic and environmental benefits of using specific alternative sustainable technologies.

Potential land afteruse options at Scorton Quarry included:

- light commercial and industrial units with focus on recycling and biofuel technology; destination leisure venue consisting of a hotel, conference facilities, fitness centre, swimming pool and indoor sports hall;
- lakeside family orientated leisure facility with camping/log cabins, associated entertainment area and recreational activities;
- mixed-use residential housing development in semi rural location within close proximity to existing services and small settlements, consisting of 30% affordable housing and 10% housing for elderly/disabled; and
- destination retail garden centre with catering franchise, retail units, outdoor plant sales area with a shop.
- Renewable heating systems for aquaculture and agriculture (greenhouse, drying, poultry, etc) were also considered.

Operational energy requirements at the quarry

Using an integrated approach to quarry design it may be possible to incorporate sustainable energy usage during its operational life, which may then also serve the final end use. This may be economically attractive, given that the potential life-span of the quarry (>10 years) is often compatible with a higher capital investment thus benefiting from low operating costs. The resulting carbon emission reductions may also be of importance given the significant emissions associated with mineral extraction and onward transportation.

The RETScreen International Clean Energy Project Analysis Software (RETScreen International, 2004) is a free tool specifically aimed at facilitating feasibility analysis of clean energy technologies and formed the basis of the energy assessments in this study.

Energy requirements for the various afteruse options were estimated using the RETScreen software and are presented on Figure 1 in comparison to the current site energy demands. The total energy demands of all the afteruses considered are of a similar order of magnitude, with the exception of the 200 residential dwellings which has a much higher demand and all have a much greater heating demand than the quarry, which requires only limited space heating for the offices.

Apart from heating the site offices, power is the primary requirement for Scorton Quarry. Other mineral

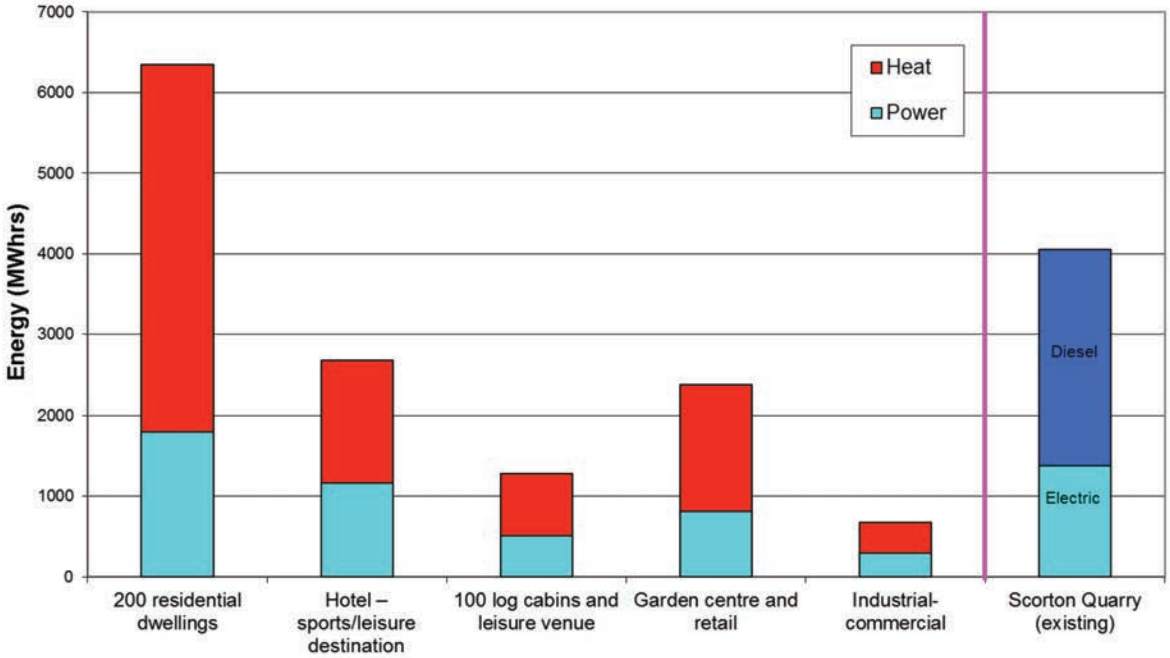

Figure 1. *Site afteruse options and energy requirements for Scorton Quarry.*

sites may have significant heating requirements as part of additional production processes, e.g. cement works and coating plants. Many of these require high temperatures, which precludes some sustainable technologies, but may benefit from heat recovery and pre-heating applications or combined heat and power production opportunities.

A range of renewable power generation technologies were considered on the basis of site data. The potential annual power outputs are presented on Figure 2 in relation to the Scorton Quarry electricity demand. Photovoltaic cells (PV) can convert only some 10-15% of the incident sun's energy to electricity and are expensive without government subsidy. Approximately 1 ha of PV or 16 small wind turbines would be required to supply the entire quarry's electricity needs, climate permitting. Installation of smaller systems such as PV and small wind or hydro turbines could contribute to an offset of the quarry's electricity requirements. However, much larger designs such as a 70m high wind turbine would be needed to meet the site's requirements entirely. It is noted that any of these schemes would only provide the site with electricity; diesel consumption represents a further 2,668 MWh/yr of energy to be offset. This highlights quite dramatically the high energy value of fossil fuels and their abundant usage in quarry mobile plant.

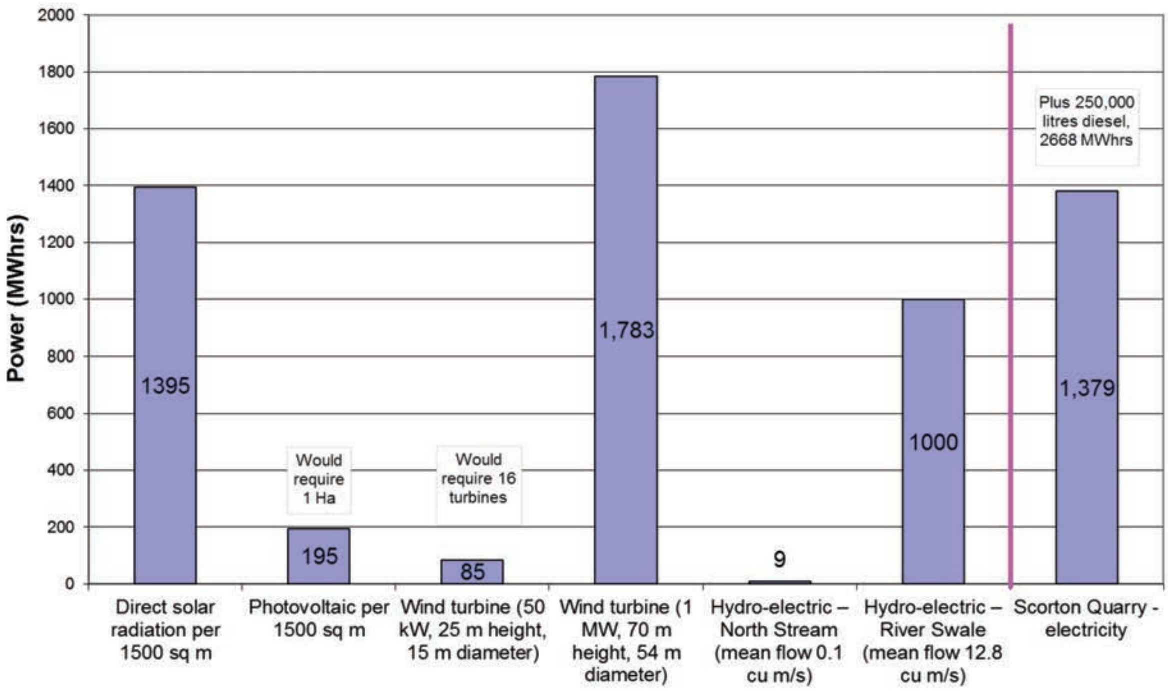

Figure 2. *Potential annual power outputs from RETs and the annual electricity demand at Scorton Quarry.*

In addition to power generation, open loop ground source heat pumps may be used to extract heat from groundwater or surface water for use in space heating applications. The direct solar radiation (Figure 2) heats the earth and recharges this ground source on a seasonal basis. Typically assuming a temperature drop of 5°C a flow of approximately 0.05 l/s is required for 1 kW of heat energy delivered. Ideally, as is the case with Scorton, gravity flow will reduce pumping costs. The calculated total available heating potential for the site by open loop was up to 50 MW peak instantaneous capacity, subject to agreement on acceptable temperature change with the Environment Agency. This could supply significant future industrial or commercial requirements or potentially some type of district heating scheme distributed to the surrounding locality.

The site power consumption at Scorton was of a similar order of magnitude to many of the site afteruses considered. Therefore, energy generation methods installed to support quarry operations would provide a valuable legacy for subsequent users. The site operational electricity requirements could potentially be met through the use of a single, 70m high wind turbine or multiple, smaller turbines. A hydro-electric facility on the Swale could generate some 70% of the site energy requirements. Sufficient ground source energy is available via an open loop to supply any of the potential site afteruses considered.

Renewable energy costs

Approximate costs for the different installations are presented in Table 4, together with an indication of the potential incentives and payback period. All costs are site-specific and are intended as guidelines only based on current prices and data from the case study.

Feed-in tariffs (FITs) are a Government incentive to promote installation of renewable power technologies. A similar scheme, the renewable heat incentive (RHI) was introduced for commercial developments in November 2011. It is noted that FITs are scheduled to run over 20 years leading to a significant long-term return on the renewable technology investment.

Conclusions

Barriers to the adoption of renewable technologies at Scorton Quarry exist, such as visual intrusions, the radar shadow associated with wind turbines, and the significant capital costs and flood issues associated with engineering works in the River Swale. However, as energy costs continue to rise the potential for use of these technologies is worth re-assessing and reviewing periodically. The wider benefits to the surrounding communities and potential for carbon off-setting should also be considered.

Sustainability is becoming increasingly important to corporate investors, on both local and global scales. As such the adoption of sustainable operations and afteruses by quarrying companies will become ever more imperative. This research indicates the potential for sustainable energy to contribute financially and environmentally to a quarry company and surrounding community both during quarry operations and during site afteruse. Rising energy costs and carbon taxes will continue to increase the financial incentives already available to help install renewable energy technology with payback terms more acceptable to the quarrying industry. The international drive to reduce carbon emissions will benefit those enlightened companies that invest in low/zero carbon technologies. Sustainability indicators are likely to become a feature of future planning applications and consumers are making increasing demands for low CO_2 emissions associated with both production and transport of goods. Many mineral operating companies have adopted CO_2 accounting procedures and offsetting through the implementation of sustainable energy technologies should feed into these mechanisms.

Barriers exist to renewable energy as discussed above and mineral companies may feel that proposals to construct a hydro-electric facility or erection of a wind turbine may raise objections from the Environment Agency or a Parish Council, potentially reducing the likelihood of obtaining planning permission. However, it may also be seen as a positive step in promoting sustainable rural regeneration if integrated at inception into the overall site master plan. The Scorton Quarry case study shows that the site power consumption was similar to many of the site after uses considered. Consequently, renewable energy generation capacity installed to support quarry operations would provide a valuable legacy for subsequent users.

The potential for the integration of sustainable technologies within quarry restoration has been recognised. Planners predict that the proposed construction of Eastgate renewable energy village in County Durham has the potential to create 150 jobs on-site and another 200 in spin-off industries (The Northern

Technology	As % of Scorton's electricity	CAPEX (£)	Feed in tariff FIT (£/kW)	Power generated (kWh)	Payback (years)
PV 1500 m^2	14	£ 728,420	0.293	195000	9.5
Wind (50 kW)	6	£ 135,000	0.24	85000	4.7
Wind (1 MW)	129	£ 1,500,000	0.094	1783000	4.3
HEP Swale (265 kW)	73	£ 1,600,000	0.11	1000000	7.6

Table 4. *Capital expenditure (CAPEX) costs of RETs at Scorton Quarry and incentives.*

Echo, 2008). The site is to be developed on a restored quarry operated by Lafarge and will utilise wind, solar, geothermal, hydro-electric and biomass to be fully self-sufficient in energy. The development is planned to promote opportunities for skilled workers in the renewable sector and will include geothermally heated public hot spa, homes, businesses, hotel, visitor centre, education and leisure facilities.

Further work remains to be done in reducing barriers to providing new sustainable land use solutions and exploring how the quarry industry can positively contribute to national sustainability indicators and/or carbon emissions through new end uses/land use options.

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REFERENCES

Aggregate Industries, 2011. URL: http://www.aggregate.com/Sustainability/Carbon-management.

Cemex, 2009. URL: http://www.cemex.co.uk/su/doc/UK_Site_Map TITLES_20August2009.xls.

Ellis, P., Healy, N., Leake, C., Smithyman, R., Ward, A., Moore, S. & Mann, D. 2008. Water-based quarry restoration: opportunities for sustainable rural regeneration and nature conservation. Report MA/6/2/013, Minerals Industry Sustainable Technology Programme. Minerals Industry Research Organisation.

Hanson, 2009. URL: http://www.heidelbergcement.com/NR/rdonlyres/1B06B8AA-5ECC-473F-9446-1053BC79ADF9/0/HansonUKsustainabilityreport2009.pdf.

HM Government, 2003. Water Act.

Quarry Products Association (QPA) 2008, Carbon Management Good Practice Guide. ESD Ltd.

RETScreen International, 2004. URL: http://www.RETScreen.net

Tarmac, 2010.Sustainabilty Report. URL: www.Tarmac.co.uk.

The Northern Echo, 2008. Published 1/2/08. Pp.5.