Tapton School Renewable Energy:

Briefing note for stakeholders

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Executive Summary

This report provides an initial assessment of the suitability of different renewable energy sources for the Tapton School Site. If funding can be secured to cover the capital and installation costs, it has been suggested that a small scale wind turbine (6kW), a solar water heating array (6MWh/year) and a biomass boiler (500kW) are all suited to the school. This list corresponds to the likely order of installation, as determined by the cost of each technology and the complexity of the design and installation process. Two sites have been identified for the placement of a wind turbine, both of which are adjacent to the car park, making use of the relatively unobstructed south-westerly aspect. This makes the device not only functional but highly visible, a key quality for raising awareness of renewable energy sources. The hardware of the turbine itself will be housed away from the school and requires no substantial modification to the building. Roof mounted solar water heaters would function to preheat water for the general hot water supply. The biomass boiler would call for a complete overhaul of the boiler house to install the boiler unit and provide storage facilities for the biomass fuel. However, assuming funding is obtained, the biomass installation will generate the greatest savings both financially and environmentally, potentially preventing 3040 tonnes of CO_2 emissions. Further investigation is scheduled to address some of the technical issues relating to the installation of solar water heaters and a biomass boiler. A series of actions are recommended to progress the installation of a wind turbine, which include the implementation of an energy efficiency policy by the school management. An outline funding plan for the turbine is provided.

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1 Introduction

1.1 Renewable energy in schools

Renewable energy generation in schools is an exciting idea that is rapidly gaining in popularity as part of a broader effort to make our schools and society more sustainable. The presence of renewable energy has benefits on several fronts beyond the environmental contribution of reduced CO_2 emissions. There is substantial grant funding available for such projects and grant funded installations have brought considerable cost savings to schools. On site renewables are a valuable educational resource that not only contribute to the curriculum but also help to raise awareness of energy and climate issues amongst students and the local community. Visible energy generation helps keep people conscious that energy is a finite and valuable resource, which can form a cornerstone of an effective energy efficiency policy.

1.2 Sheffield Community Renewables (SCR)

Sheffield Community Renewables (SCR) is a not-for-profit voluntary organisation, set up to support the development of local renewable energy projects within schools and communities. SCR has entered into a partnership with Tapton School to investigate the possibilities for renewable energy generation for the school and to facilitate the funding and installation of appropriate renewable energy sources. This document summarises the renewable energy options for Tapton School as assessed by SCR.

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2 Renewable energy options

2.1 Selection of suitable renewable sources

Though there are numerous renewable technologies available, this report concentrates only on those that are potentially suitable for a school scenario. This section presents those identified technologies and further narrows them down to those that are specifically suitable for Tapton School. Each technology is briefly explained, together with an approximate costing breakdown.

- **Biomass CHP:** CHP, or combined heat and power units, are designed to meet the electrical demand (e.g. by using a combustion engine running on a bio-fuel to turn an electrical generator) and use the waste heat from the combustion process for space or water heating applications. The technology in its current state has a minimum plant size of around 100kW electrical output. However the space requirement for installation and constant energy output mean this technology would not be suitable for Tapton.

- **Small Scale Wind Turbines:** Though recent studies have shown this technology to perform poorly in many built up areas, Tapton's location (with its unobstructed south-westerly view) makes it a good candidate for a small scale wind turbine installation. Careful consideration of the installation site (with respect to buildings, vegetation and the landscape) could allow suitable performance.

- **Solar Water Heating:** Utilises solar radiation to heat water either by a flat plate collector or evacuated tubes. It is a simple and proven technology that works well to preheat water (prior to passing it into the main boiler) at Sheffield's latitude, which would make it quite appropriate for Tapton.

- **Biomass Heating:** If designed and installed correctly biomass heating could be the most cost effective renewable energy source and provide the greatest carbon savings. However these systems raise a number of logistical problems as this would have to be a 'retrofit' installation and would require the receiving and storing of pelletised biomass fuel.

- **Medium/ Large Scale Wind Turbines:** Noise from these larger turbines means they must be positioned away from schools. A reasonable distance would be at least 200m from school buildings and 500m from residential buildings. As far as we are aware Tapton does not have such space available, therefore this option can be discounted.

- **Ground Source Heat Pump:** This technology uses the same process as a refrigerator but on a much larger scale. The heat is taken out of the ground and 'concentrated' before being used to heat water for space heating applications. This can be an effective technology and is being installed on a number of new school buildings; however it would require significant amounts of excavation for ground loops (for extracting the heat) and modifications to the heating system, as the temperature of the concentrated heat is lower than for a conventional boiler. Due to the use of electricity rather than gas to run the compressors, there is the potential that it can cost more than a gas boiler only system. Calculations suggest that this technology would not be cost effective for Tapton School.
- **Roof Mounted Photovoltaic Panels:** Photovoltaic (PV) panels convert solar radiation into electricity and are most effective in direct sunlight. The cost per unit output is relatively high when compared to other technologies; however they provide a simple carbon reduction technology requiring minimal maintenance.

The above discussion of options is relatively simplified, but leaves four technologies to study further: small scale wind turbines, solar water heating, biomass heating and photovoltaic panels.

2.2 Assumptions of analysis

It must be recognised that in all cases involving renewable technologies, the heat or power output of the devices are dependant upon the availability of the natural resource (e.g. wind or solar radiation), which by their nature are variable. All expected outputs within this document are conservative estimates, but are still dependant on a variable natural resource and so cannot be taken as an absolute minimum output.

It is also important to emphasise that the cost of both electricity and gas can fluctuate and all calculations are based on the cost of these two commodities at the time of writing. Though the general trend is for these prices to increase (making these schemes more economically favourable) there is the potential for reduced revenue if the price of electricity and gas goes down in the future.

3 Small scale wind turbines

3.1 Wind potential at Tapton School site

As a first pass estimate we can use the NOABL database to consider the average wind speed, which for Tapton School at postcode S10 5RG is 5.1 m/s at 10 m, rising to an estimated 6.3 m/s at 45m. This is a good wind speed but not excellent, and is a calculated wind speed based on local topography that does not take into account buildings and vegetation, which can have a major effect on the annual average wind speed.

The school has a weather station on the roof terrace of one of the blocks, which has been recording wind speed since January 2008. Data from this shows wind speed to be lower than the NOABL estimate, with the average wind speed being 1.2 m/s for 5 months of data. This is very low and would provide extremely low output from a wind turbine. However, while the location of the weather station may be ideal for teaching purposes, it is not best located for measuring wind speed. The building it is mounted upon will have a considerable effect on the flow of air and therefore the recorded speed; the predominant wind direction is shown to be North-Easterly, which suggests a fault with calibration or that the buildings are having a major effect, as in this location wind direction is predominantly South-Westerly.

Figure 1: Proven 6kW wind turbine

3.2 Estimated power output

The power output of a wind turbine is proportional to the cube of the wind speed, therefore a small increase in wind speed gives a big increase in kWh output. If we can achieve the NOABL estimate of 5.1 m/s on a 15 m mast, the expected load factor is 11% and is used to describe the turbines actual output (for this case it effectively means that the turbine will function with an average output of 0.66kW over the entire year). A 6kW turbine would generate on this basis:

$0.11 * 6kW * 24hours * 365days) = 5,782$ kWh per annum

The cost of a 6kW turbine is approximately £20,000. If we assume all electricity is used on site (offsetting a current commercial electricity price of 7p/kWh) and the ROC (Renewables Obligation Certificate) value is claimed (4.5 p/kWh), the turbine would produce an effective annual revenue of (11.5 x 5782/100) £665.

Over an estimated 15 year lifetime of the turbine:

- Energy saved = 86,730 kWh
- Carbon saving = 45,300 kgCO_2 (using 5 year rolling average grid electricity factor of 0.523 kgCO_2 /kWh)
- Total revenue (un-discounted) = £9,975; however this does not take into consideration rising energy costs or annual maintenance costs.

3.3 Location considerations

The car park is the most appropriate site for a wind turbine; two possible sites are shown on the map in appendix A. These are a suitable distance from any trees or nearby structures that could reduce wind speeds and are well situated for the prevailing south westerly-winds. In addition, this site is both easily accessible for installation and highly visible to all visitors of the school.

3.4 Installation considerations

Installation of a wind turbine would not require any major modifications to the fabric of the school building. As well as the mast itself, it would require an inverter to be fitted in the plant room and cabling to connect the system to the school.

4 Solar thermal water heating

4.1 Solar thermal potential at school site

This is a much simpler technology than wind turbines to assess and the output is more certain. It is likely that the panels would be connected into the existing heating system to provide a preheat for the building hot water supply. Solar thermal heating units have proved to be very effective at the latitude of Sheffield and do not require direct solar radiation to function (meaning that the panels will still function even if the solar radiation is diffuse, such as on an overcast day).

4.2 Estimated power output

For optimum function, the solar heating panels would need to be positioned on a South facing roof inclined at 30 degrees from horizontal. These parameters should allow the units to capture about 600 kWh/m^2 of usable heat per year. Therefore a 10 m^2 array should provide 6,000 kWh/year.

Over an estimated 15 year lifetime of the hot water panels:

- Energy saved = 90,000 kWh
- Carbon saving = 17,100 $kgCO_2$ (using natural gas factor of 0.19 $kgCO_2/kWh$)
- Total revenue (un-discounted) = £2,505; however this does not take into consideration rising energy costs. Maintenance costs should be small (perhaps £50 per year for cleaning).

4.3 Installation costs and considerations

Installation costs vary depending on the existing structure but a conservative estimate for an installed $10m^2$ solar hot water panel would be £9,000. If the 6,000 kWh per year was to offset gas demand, at approximately 2.5 p/kWh and burnt in a 90% efficient boiler, the annual financial saving would be £167. Further technical investigations are required to establish if solar panels can be fitted to the roof without risk to its integrity, and that they could be connected to pre-heat water for the existing hot water system.

5 Biomass heating system

5.1 Viability of a biomass installation at Tapton School

The concept of biomass boilers from a renewables perspective is that they use fuel that is derived from organic matter. In essence then trees harvested to power the boiler have extracted the majority of their carbon content from the atmosphere. If new trees are grown to meet the demand then the process is nearly carbon neutral (ignoring processing and transport costs of fuel pellets) and the carbon that is released from the boiler is essentially being soaked up by the growth of new trees.

As the costs of natural gas and oil increase, the viability of woodchip (even from a retrofit point of view) becomes more apparent. Typical costs of woodchip can range from £20 - 40 per tonne for low grade fuel (though increased maintenance costs will be incurred) to £75 - 100 per tonne for higher grade pellets. If there is a sufficient source of fuel in close proximity, transport costs can be kept low and relatively simple structures are required to store the fuel (unlike oil etc).

Over an estimated 20 year lifetime of a 500kW Biomass boiler:

- Energy saved = 16 GWh
- Carbon saving = 3.04 million kgCO_2 (using natural gas factor of 0.19 kgCO_2/kWh)
- Total savings (undiscounted) = £80,000 (gas saving including cost of biomass fuel)
- Maintenance costs would be in the range of £1,000 per year, but would depend on the available fuel.

The typical format of the biomass boiler circuit would be to have the boiler in conjunction with a heat exchanger, heating the water in large accumulator tanks, which would be used for the high volume central heating load. An additional heat exchanger could be used to heat the hot water tank (for human use and consumption) from the same boiler unit. An audit of the current boiler system would be required to develop the best route to install the unit (whether to retrofit a new boiler to the current hot water storage systems or to install a whole new system).

5.2 Installation and operational costs

Typical costs of systems (installed but without changes to infrastructure or construction work) are in the order of £80k - 100k and payback periods can be quite rapid when compared to other renewable technologies although they are dependent on gas and biofuel prices.

The cost of transportation of the pelletised fuel will depend upon the location of the source, and the volume that can be shipped in a single delivery. In addition there is an ash product that will need to be removed. However it may be possible to set up a scheme where this waste ash is used as a fertilizer and further revenue gained.

The maintenance costs of a biomass system using solid fuel will be higher than an equivalent gas boiler. These increased costs are principally due to the need to extract and dispose of waste ash products and the increased complexity of the fuel feed system.

5.3 Further investigation

To enable an extensive analysis of the viability of a biomass boiler, further investigation is needed into how compatible the current heating circuit is with a suitable biomass boiler. In addition, spatial requirements and positioning need to be considered in order to asses whether a fuel storage facility can be installed and the viability of delivering the fuel. Finally, a suitable source of woodchip or pellet needs to be found (ideally as locally as possible to minimise the associated transport costs both financially and environmentally).

6 Solar photovoltaic cells (PV)

6.1 Viability of PV for Tapton School

PV cells are less efficient at converting solar energy than solar hot water panels, with the output approximately 162 kWh/year/m^2 of panel. Tapton could install a 3 kW PV array on the roof of the school, which would require approximately 18m^2 of PV and generate 2,890 kWh of electricity per annum. The cost of the array would be around £15,000. The electricity carbon factor and electricity cost estimate can be used (as in the case of the wind turbine) to give an estimate for the output of the device over a 15 year period.

Over an estimated 15 year lifetime of the PV panels:

- Energy saved = 43,362 kWh
- Carbon saving = 22,680 kgCO_2
- Total revenue (un-discounted) = £4,987, however this does not consider rising energy costs. Maintenance costs should be minimal (predominantly cleaning).

It should also be noted that these figures are included for comparison with the wind and solar hot water technologies. However, PV panels should have a 30 year lifespan, thus lifetime savings can be doubled if discount factors are not considered.

7 Comparison of technologies

Table 1: Comparison of different renewable technologies for Tapton School

Technology	Wind	PV	Solar thermal	Biomass	GSHP
Example unit	Proven 6kW	3kW peak ($18m^2$)	6MWh /year	500kW	20kW hiriz. coils
Unit cost (£k)	20	12 - 15	9	120	26
Annual output (MWh)	5.8	2.9	6	800	25 - 30
Unit life (years)	20	15	15	20	20
Energy saved (MWh)	87	43	90	16,000	750
CO_2 saved (tonnes)	45.4	22.7	17.1	3040	38.6
Cost per tonne CO_2 (£)[1]	366	805	526	40	646
Annual operating and maintenance cost (£)	300	50	50	1000	200
Annual revenue (£)[2]	350	250 - 280	100-120 (saving)	3,000 (saving)	-300

[1] This has been calculated is accordance with the Low Carbon Buildings Program application criteria

[2] Assuming initial installation is 100% grant funded

The analysis suggests that the most viable technologies for the Tapton school site are a biomass boiler, a wind turbine and solar water heating. These afford the lowest cost per tonne of carbon dioxide saved (£40 and £366 and £526 per tonne respectively, calculated according to the criteria of the LCBP (Low Carbon Buildings Program)). Each of these technologies is well within the threshold set to assess potential sites. Figure 2 compares the viability of each technology according to the LCBP thresholds. The high capital cost per unit of energy produced by the photovoltaics mean that the cost per tonne of CO_2 emissions prevented is relatively high at £805/tonne. These units are less effective due to Sheffield's latitude and have a high initial cost. The average cost of produced electricity is very likely to be higher than that bought from the mains (though the cost of mains electricity is likely to go up in the future). Ground source heat pumps do not appear to create a significant benefit, as a result of the electricity required to run the compressor. As a result of this driving energy requirement (and associated thermodynamic losses), the actual carbon dioxide saving is fairly low (approximately 40 tonnes) and as such the cost per tonne of carbon dioxide saved is high (£646/tonne). This is probably not a viable technology for the school.

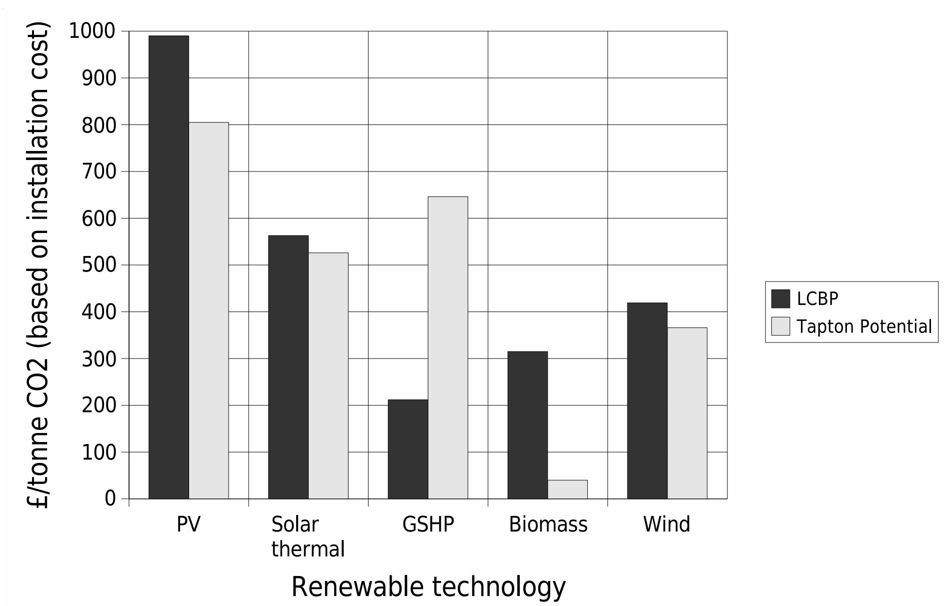


Figure 2: Graph of suitability of different renewable energy technologies according to the LCBP

8 Conclusions and next steps

On the basis of carbon savings per unit cost and potential revenue for the school, the most appropriate technologies for Tapton are wind, biomass heating and solar hot water. Any effective technology to make the building more sustainable should be a valuable educational resource; however the high visibility of wind and solar technologies makes them particularly desirable in this respect. We therefore recommend a wind turbine and solar hot water heater as the immediate priorities for the future (and in that sequence). Given that the largest reduction in CO_2 emissions from the school would be given by a biomass boiler system, this should also be investigated in more detail to identify whether it is technically feasible for the school site.

The suggested next steps for the renewable energy programme at Tapton School are:

- Low Carbon Buildings Program approved installers to inspect site and provide quotes for a 6 kW wind turbine and solar water heaters. Ideally this would occur over the summer break.

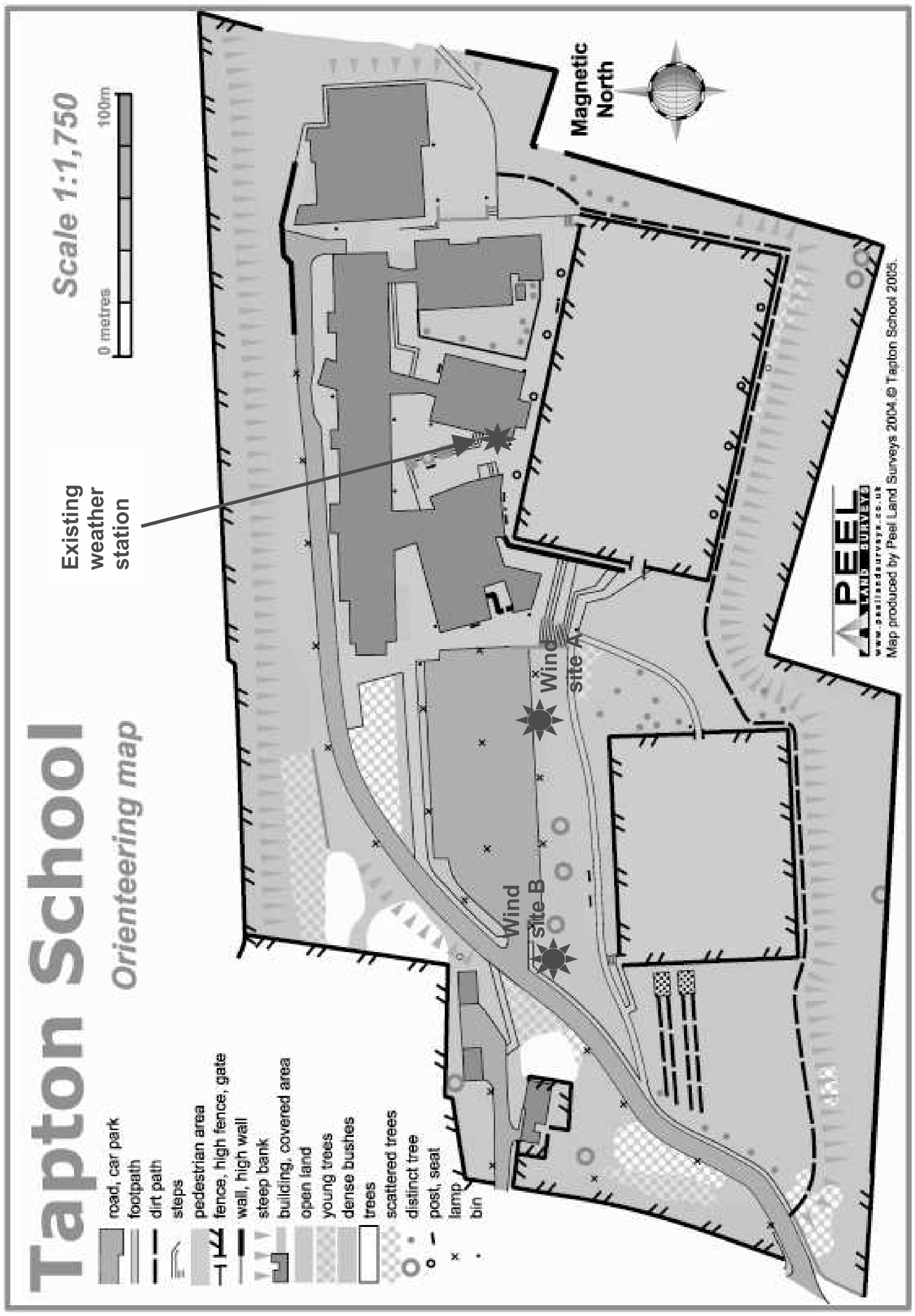
- Ongoing technical consultation between SCR, LCBP installers and Interserve over solar water heaters, wind turbine and longer term possibility of biomass heating.

- Implementation of an energy efficiency policy by the school management. The Interserve Education Energy Action Plan provides a valuable structure for helping implement and monitor such a policy and we recommend that this resource is made full use of.

- Funding plan to be proposed by SCR.

- Model for alteration to contracts between Interserve and Sheffield City Council to address issues of ownership of installations and financial benefit. This will also include insurance and maintenance provisions. This will be prepared by SCR.

9 Appendix A: Map of potential sites for turbine



10 Appendix B: Funding outline for 6 kW wind turbine

The cost of a Proven 6kW wind turbine system, including installation, is approximately £20 k. Phase 2 of the Low Carbon Buildings Program will provide a grant for up to 50% of the cost of the turbine and installation if minimum predicted performance standards are met. This study shows that a turbine on the Tapton site should exceed these standards and so £10 k of the cost of the turbine can be met from this source. It is proposed to raise the remaining capital through the following sources:

- Grant applications to charitable trusts established to encourage renewable energy generation including:
  - The Scottish Power Green Energy Fund
  - The Community Sustainable Energy Fund - part of the Big Lottery Fund
  - The E.On Source Fund
- Approaching local businesses who may wish to sponsor the project.
- An active fundraising program organised within the school and local community could provide funds in the region of £1 k. Although this is a small fraction of the total, this would provide a valuable route for students and the local community to participate in the scheme and thus achieve a genuine sense of investment in the project.