SCIENCE OUTDOORS

A practical activity, linking trees with energy

INTRODUCTION

Renewable energy, including the potential use of biomass fuels, is a hot topic. It appears throughout the new GCSE specifications and its profile will continue to grow. Intuitively, most pupils think that renewables are a 'good thing', and that we should 'do more' to develop them. The difficulty for the teacher is that this response is rarely based on any sense of scale, particularly one which relates personal consumption to environmental impacts. One solution may lie outside your classroom, and all you need is a tree, a piece of string and a ruler.

Take your pupils outside the classroom to the nearest tree – and even the most urban school will have a London plane or sycamore nearby - and ask "if this tree was felled and used for biofuel to provide heating and hot water how many of you could it support over the next year?" The purpose of the activity is to test their answers/hypotheses.

METHOD

1.Select your trees. Although this activity can be applied to a single tree it will work best with a group of trees which can provide pooled data and greater scope for group work and extended discussion (see below). There is no need for identification because the data (Table 1) assume an average value of timber productivity for each tree size (see step 2 below).

2. Measure the girth (circumference) of your tree(s) (at chest height) – you can do this with a piece of string which is marked and then measured with a ruler. Then refer to Table 1, select the row in column a which is the closest to your measurement and record your entry for that size in the tally column (column f). Repeat for each tree available in your sample area.

3. The tally column can then be converted into the total number of pupils whose annual energy needs could be supported by felling your sampled trees. This is done by multiplying the number of trees of a certain size (column f) by the number of pupils each tree could support (column e). For example, a measured girth of 202cm would be entered as a tree with girth 201cm, which would support 9 pupils for a year. In the completed examples in Table 1, the 6 trees which measured close to 201cm would be able to supply enough woodfuel to provide heating and hot water for just over 54 pupils for one year. The total for all 12 trees in this sample is 112.8 pupils.

4. Stand back and admire the dawning realisation…do we really need that many trees (and land area – see *Impacts in your area* below) if we keep consuming at our present rate?

ASSUMPTIONS AND EXTENSIONS

The figures in Table 1 involve a number of assumptions, each of which unlocks potential extension activities.

Girth (a) to Volume (b) The amount of timber a tree will produce depends on a variety of factors, including species, age, height and management. To assess how productive a tree is likely to be, foresters take a sample of trees in their area, identify them and then use their girth and height to allocate a Tariff Number (Matthews and Mackie, 2006). The higher the Tariff Number, the greater the volume of timber expected for that girth size. For example, a single tree with a 100cm girth could be expected to produce 0.25 cubic metres of timber if it has a Tariff Number of 10, but would produce 1.45 cubic metres in Tariff Number 60. The figures in Table 1 assume a Tariff Number of 50, which is appropriate for a productive healthy tree of indeterminate species, likely to have been well managed in good and uncrowded (e.g. parkland and/or well thinned woodland) growing conditions.

Volume (b) to Mass (c) Assumes one cubic metre converts to 0.66 tonnes (as advised by a woodfuel expert). The actual conversion will depend on species and moisture content, but could be tested in the classroom with real chips/logs.

Mass (c) to Energy Content (d) The calorific value per unit of mass will be approximately the same between species. Therefore, 1 kg of beech will provide the same energy content as 1 kg of spruce. The main impact on energy content is the moisture content. Freshly cut timber will be approximately 55% water and produce 6.61GJ per tonne, oven dried timber which is about 18% water will produce 17GJ per tonne. The table assumes air-dried wood, 35% moisture content, providing 10.65GJ per tonne. Again, the calorific value of different types of wood and/or moisture contents could be tested in the laboratory. This practical is beyond the scope of this paper.

Figure 3. Magnificent parkland trees such as this rural oak or its urban equivalents can provide surprising results when measured for potential woodfuel productivity, leading to preconceptions about personal energy consumption and production being questioned.

Energy content (d) to pupils supported (e) The average secondary pupil in England and Wales will use 1632kwh per year (1150kwh for primary school pupils) (DfES 2002/3).This converts to 5.87GJ. However, burning woodfuel only makes sense if it is used directly for heating airspace or hot water. Modern condensing boilers can be 90% efficient for this purpose. Their efficiency falls to 40% for conversion to electricity. Table 1 assumes that the boilers are providing heat and hot water, which this activity assumes account for 60% of an average pupil's energy needs. Therefore, each pupil needs 3.91GJ each year. The assumptions throughout this step have great potential for extension work: why are boilers inefficient for producing electricity? (link to power stations); what is your consumption compared with the average consumption? (in schools); what are the possible impacts of climate change? (heating consumption falls the further south you travel, but with climate change air-conditioning might replace heating in the south!).

IMPACTS IN YOUR AREA

The activity assumes that no other energy is 'lost' in these steps from tree to heat/hot water. Obviously, this is unrealistic with felling, management (including herbicide, pesticide application and reduction of logs to wood chips if needed) and transport consuming energy. The latter is the reason why woodfuel is mostly sourced from within 20km, and preferably much nearer. Most pupils are surprised by how few people can be supported by even the biggest of trees. This becomes even more surprising when considering how much area would be needed to support a lifetime's needs. A tree with a girth of 100cm will have taken 30-75 years to get to that size, depending on species and growing conditions. So, if a tree takes
50 years to get to this size, and then it provides enough energy for two people, starting from bare ground we will need to allocate enough space to have one tree planted every two years and wait 50 years for the first planting to mature, before we have a sustainable supply. Multiply that up for a school and the landscape impacts become apparent.

Data comparing land areas needed for different renewables are sparse and often contentious. However, Ausubal (2007) has published some recent figures based on potential energy production per unit area in North America (see Table 2). These can be used to assess the possible use of local sites, and the costs and benefits (physical, social and environmental as well as economic) of doing this.

.Unmanaged scrubland can provide a fertile ground for woodfuel investigations with

A group discussion will usually identify the need to reduce energy consumption; hopefully, pupils will conclude that chopping down those trees adorning our woodlands, parks and pavements is not a sustainable solution and that they have much more value for amenity, recreation and conservation purposes! Short Rotation Forestry (eg. willow or poplars) or biofuel (eg. elephant grass) is another solution. They can be much more productive than common woodland trees, and available for harvesting in a very short time – as little as 1-2 years - but even for these fuel crops each of us will need approximately 0.2ha (44 x 44 metres) each to meet our annual heating/hot water needs (at present levels of consumption and efficiency).

The future

This is a work in progress. It was first 'field tested' in January 2007 at the ASE's annual meeting, as part of one of the ASE's Outdoor Science Working Group workshops (see below for contact details). Further tables will be produced to allow for different species in different situations, but the present conversions and assumptions should provide a robust, active and accessible (physically and conceptually) introduction to renewable energy teaching. It could, and should, make links across all science disciplines - organisms and health, chemical and material behaviour, energy and environmental impacts and management are all covered. And it is fun.

References/web links

Timber yields

- Matthews, R.W. and Mackie, E.D (2006). *Forest Mensuration. A handbook for practitioners.* Forestry Commission, Edinburgh (a very technical book, only appropriate for further research/adaptation by teachers)

Tree identification

- Oldham, J. (2003) *The Tree Name Trail*. Field Studies Council, Shrewsbury. An introductory fold-out chart for common species
- May, A. & Panter, J. (2000). *A guide to the identification of deciduous broad-leaved trees and shrubs in winter.* Field Studies Council, Shrewsbury. A comprehensive key enabling winter identification

Schools energy consumption

- http://www.dfes.gov.uk/rsgateway/DB/SBU/b000477/bweb02-04.pdf. Web site statistics for schools energy consumption, broken down into areas/regions.

Energy conversion.

- www.dfes.gov.uk/valueformoney/docs/VFM_Document_9.doc. A DfES schools-based document useful for supporting energy saving discussions etc.

Energy productivity comparisons

- Ausubel, J.H. (2007). Renewable and nuclear heresies. *International Journal of Nuclear Governance, Economy and Ecology*. **1** (3): 229-243 A contentious paper which has spawned many responses on internet blogs etc., some of which could be used to support group discussions, topic work.

TABLE I

AVERAGE' TREES DATA

GIRTH (cm)	VOLUME (m3)	MASS (kg)	ENERGY CONTENT (GJ)	HOW MANY PEOPLE WILL THIS TREE PROVIDE ONE YEAR'S HEATING AND HOT WATER FOR?	TALLY INDIVIDUAL TREES IN YOUR AREA	TOTAL (pupils supplied for one year at present average consumption)
a	b	c	d	e	f	g
22	0.01	3.3	0.0	0.0		
31	0.07	44.9	0.5	0.1		
41	0.15	101.0	1.1	0.3		
50	0.26	171.6	1.8	0.5		
60	0.39	257.4	2.7	0.7		
69	0.54	356.4	3.8	1.0		
79	0.72	475.2	5.1	1.3		
91	0.98	646.8	6.9	1.8		
100	1.21	798.6	8.5	2.2		
110	1.46	963.6	10.3	2.6	I	2.6
119	1.73	1141.8	12.2	3.1		
129	2.02	1333.2	14.2	3.6		
138	2.33	1537.8	16.4	4.2		
151	2.79	1841.4	19.6	5.0		
160	3.15	2079.0	22.1	5.7	III	17.1
170	3.54	2336.4	24.9	6.4		
179	3.95	2607.0	27.8	7.1		
188	4.39	2897.4	30.9	7.9		
201	5.00	3300.0	35.1	9.0	~~IIII~~ I	54
210	5.48	3616.8	38.5	9.9		
220	5.99	3953.4	42.1	10.8		
229	6.52	4303.2	45.8	11.7		
239	7.07	4666.2	49.7	12.7		
248	7.64	5042.4	53.7	13.7		
261	8.44	5570.4	59.3	15.2		
270	9.07	5986.2	63.8	16.3		
279	9.72	6415.2	68.3	17.5	I	17.5
289	10.40	6864.0	73.1	18.7		
298	11.10	7326.0	78.0	20.0		
311	12.00	7920.0	84.3	21.6	I	21.6
320	12.80	8448.0	90.0	23.0		
330	13.50	8910.0	94.9	24.3		
339	14.30	9438.0	100.5	25.7		
349	15.10	9966.0	106.1	27.1		
361	16.30	10758.0	114.6	29.3		
371	17.10	11286.0	120.2	30.7		
TOTAL					**12 trees**	**112.8**

TABLE 2

RENEWABLE ENERGY: COMPARISONS OF LAND AREAS NEEDED

	ENERGY PRODUCTIVITY (WATTS PER HECTARE)	NUMBER OF STUDENTS SUPPORTED PER HECTARE*
Hydro (large scale dams)	120	0.07
Biomass (unmanaged woodland, averaged over renewable cycles)	1200	0.70
Biomass (managed for biomass, averaged over renewable rotation cycles)	12000	7.35
Wind (based on large commercial turbines on wind farms)	1200	0.70
Photovoltaic	60000	36.75

Source: Ausubel, 2007
*assumes average student's heating/lighting annual consumprion of 5.67GJ

This resource was written by Steve Tilling, Director of Communications at Field Studies Council, and is reproduced, with permission, from the Association for Science Education (ASE) journal. The activity, and others like it, will be developed further by the ASE’s Outdoor Science Working Group. Visit http://www.ase.org.uk/htm/teacher_zone/outdoor_science/outdoor_science.php for more details.