Section 1: Energy, Renewable Energy and Carbon Basics

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1.1 Energy basics

‘Energy’ can be defined as ‘the ability to do work’ and is measured in Joules (J). The rate at which energy is generated or used is measured in Watts. One Watt is one Joule per second – (Js^{-1})

The unit of Watts most commonly used when discussing energy consumption is the kilo Watt – i.e. 1000 Watts – or 1kW.

1.1.2 Energy rating

Electrical appliances are rated in kilowatts. So, for example an oil filled radiant heater is rated at 1.5kW. This means that when the heater is switched on it will immediately consume up to a maximum 1.5kW.

Where large amounts of energy are generated or consumed, the units used are more likely to be in one of the following formats; Mega Watt (1,000,000 Watts or 1MW), Giga Watt (1,000,000,000 Watts or 1GW) or even Tera Watt (1,000,000,000,000 Watts or 1TW).

1.1.3 Energy consumption

Units of energy consumption are usually expressed in terms of the amount of energy used over a certain period – the standard term for this is kilowatt hours or kWh i.e. the amount of energy consumed over an hour.

The 1.5kW heater if left on for an hour with a constant electrical supply will therefore consume 1.5kWh of energy. By the same token, a 60W light bulb left on for an hour will consume 0.06kWh = 60 Watts X 1 hour = 60 Watt hours or 0.06 kWh.

Electricity is sold by the kWh, which equals 1 unit. The current domestic tariff is around 13p per kWh. Therefore keeping the electric heater on for 1 hour will consume 1.5 units of electricity – 19.5p.

1.1.4 Energy generation

The same rationale is applied to energy generation. Generators are rated in kW or MW, indicating the maximum that can be generated at any moment. If a 1kW generator is operating at full capacity for 1 hour it will generate 1kWh.

However, the amount of energy generated will depend on how much useful energy is available to power the generator. It will only generate to its maximum rated level if it is supplied with sufficient useful energy. This applies equally to a small diesel generator or a wind generator, the only difference is that a small diesel generator will generally either be full on (with fuel), or off (no fuel) whereas the output from a wind generator will vary with wind speed.

1.2 Renewable energy basics

Understanding some renewable energy basics will help you to work through what may be possible for your community. Below are some typical questions that arise as people seek to understand how renewable energy works and why they should consider using it.

1.2.1 What are the useful sources of renewable energy?

The main sources and how they can be used are summarised in the table below;

Source	Utilisation	Output
Sunlight - heat	Solar water heating	Hot water
Biomass - wood	Combustion – boiler or stove	Heat
Sunlight – heat from sun transferred to soil, air or water	Ground source heat pump Air source heat pump Water source heat pump Passive solar	Heat and hot water
Sunlight - photons	Solar photovoltaic cells (PV)	Electricity
Wind	Wind turbine	Electricity
Water	Hydro turbine	Electricity
Biomass - wood	Combustion – boiler (+ steam turbine if electricity generation is desired)	Heat (and electricity)
Biomass – biodegradable matter	Anaerobic digestion (decomposition without oxygen, producing methane gas) - can also use the gas to generate	Heat (and electricity)

	electricity if desired	
Wave (wind)	Floating or shore based electrical generators converting kinetic energy from waves.	Electricity
Tidal	Underwater electrical generators converting kinetic energy from tides	Electricity

1.2.2 Can we get free heat and power?

As sources of renewable energy, like the wind, are free, fuel cost will be free (the exception being biomass which will have a cost in terms of sourcing pellets, woodchip or logs). Ironically, though the fuel is free or low cost, the capital investment required to harness the renewable energy can sometimes be quite significant compared to traditional (fossil fuel) based systems. All systems need to be regularly maintained, just as with traditional systems.

The Scottish Government provides grant assistance to community groups undertaking renewable energy projects, more information is available here:

http://www.energysavingtrust.org.uk/scotland/Scotland/Scottish-Community-and-Householder-Renewables-Initiative-SCHRI and http://www.communityenergyscotland.org.uk/grant-funding.asp and in section 9, Funding and financing your project.

For some communities with abundant renewable resources, the use of renewable technologies will allow cost savings compared with traditional energy fuels and equipment.

1.2.3 How, in practice, does it compare with using traditional energy sources?

From the user's perspective, there is no reason for any significant difference in operation of renewable systems compared with traditional sources – user-friendly control panels are standard.

With certain technologies, however, there is a requirement to be aware of the limits of operation and to think a bit more carefully about energy requirements. For example, a ground source heat pump can be ideal for providing background warmth, but cannot react instantaneously to provide immediate additional heat.

However, the on-going cost of renewable energy based systems is likely to be lower than those based on fossil sources. Fossil fuels are widely expected to increase in cost as global demand increases. In addition, as the use of renewable systems increase, economies of scale will mean installation costs will become more competitive.

In terms of heat supply, the key practical difference between biomass and fossil energy sources is their *energy density.* Energy density is a measure of how much energy is stored per unit mass of the material in question. In general, renewable energy sources are less energy dense then fossil sources. This has two practical implications:

- More space to store or extract the energy source is required;
- It takes longer to harness an equivalent amount of useful energy.

So, for example, you will need a larger storage facility for, wood chips than for oil for an equivalent heat output.

1.3 Carbon Calculations - basics

Energy consumption is one of the main sources of man-made carbon dioxide emissions to the atmosphere.

1.3.1 Carbon (C) or Carbon Dioxide (CO_2)?

Carbon dioxide is one of the greenhouse gases that contribute to global warming, but often statistics and information refer to carbon only. This does not really matter as long as there is a consistency in which is used.

Emissions of either C or $C0_2$ are often expressed in kilograms (1000g) or tonnes (1000kg) but it is important to remember that CO_2, as a molecule of carbon plus two molecules of oxygen, weighs more – 3.67 times more. For this reason, any figure for the weight of CO2 will be 3.67 times more than the figure for carbon alone.

1.3.2 Is carbon dioxide the only greenhouse gas?

Greenhouse gases are those gasses that trap heat in the atmosphere and listed below are the six most important ones as per Kyoto protocol.

Greenhouse gases
Carbon dioxide
Methane
Nitrous oxide
Hydro-fluorocarbons
Per-fluorocarbons
Sulphur hexafluoride

Carbon dioxide and methane are the main greenhouse gases that arise from human activities. Water vapour is also an important greenhouse gas as it traps heat in the atmosphere.

Carbon dioxide is typically produced when something is burnt to produce energy. Methane is produced mainly by bacteria which decompose organic matter in anaerobic conditions i.e. where there is no oxygen – typically in a land fill site, or in coal mines, or in cattle rearing.

(Controlled anaerobic digestion uses the methane released as an energy source instead of releasing it to the atmosphere, see section on 4.4.2, anaerobic digestion.)

Natural sources of methane include wetlands and peat bogs. Although far less methane is emitted than carbon dioxide, methane is 23 times more effective at trapping heat in the atmosphere and is therefore a more potent greenhouse gas per tonne. Anaerobic Digestion technologies can capture methane generated by the decomposition of organic matter, and use it for heat or electricity generation.

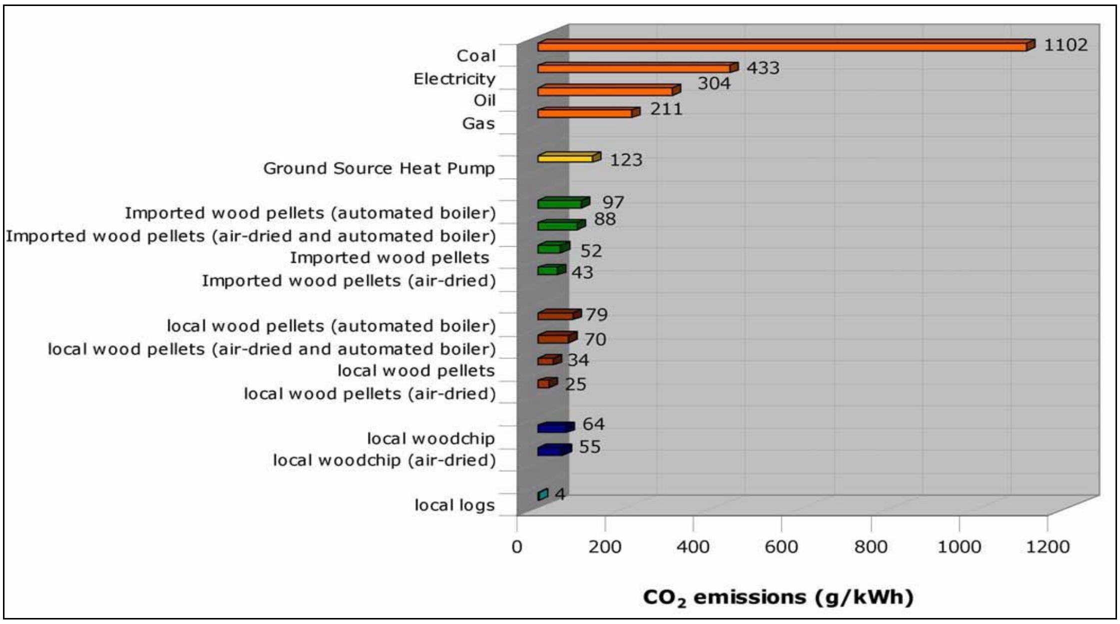
1.4 Renewable energy and carbon emissions

Substituting energy from fossil fuels with renewable energy is an important way to reduce carbon dioxide emissions. This is because when fossil fuels (coal, gas oil etc) are burnt and carbon dioxide is produced, there is no way of replenishing that resource or securing the carbon dioxide emitted.

Renewable energy sources such as wind, wave, tidal, hydro and solar are all carbon free fuels, with capture of the energy at locations where the resource is abundant. Scotland has one of the best wind, tidal and wave energy resources in the world and also has a high amount of hydro resource available. Carbon dioxide emissions are created in the construction of plant and equipment, but studies suggest that the CO_2 emitted during manufacture of plant is offset after the first few years of operation, given that the renewable technology displaces energy previously sourced from fossil fuels.

Biomass – wood and biogas – when combusted as fuels do create carbon dioxide emissions but as biomass resources can be replanted and as the growth cycle absorbs CO_2 during the life of the plant, essentially this is seen as CO_2 neutral. However there are CO_2 emissions associated with the transport of biomass fuel from resource area to end use location. Where this does happen, it is at a much reduced level in comparison to fossil fuels as biomass resources are usually sourced from local supply chains.

The relative carbon dioxide emissions for biomass and fossil fuels (excluding construction of plant) are presented below.



The Carbon balance of wood fuel, fossil fuels and ground source heat pumps
(From: Northern Wood Heat – The Carbon Balance of Wood Fuel (Highland Birchwoods / Northern Woodheat; Northern periphery Programme, 2007).

1.5 Community relevance

For communities to engage their members on carbon reduction and energy projects it can be useful to explain and promote the benefits of acting as a group. There are a great deal of opportunities, support and momentum to be gained from acting collectively as a community group to address concerns of energy security.

This toolkit explains how this can be achieved practically in terms of the technologies involved, size and types of projects (covered in District Heating, Off-grid Solutions, Generating and Selling Electricity and Securing Community Benefit from Commercial Renewable Energy Developments), community organisation and funding availability.