solarcentury

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Displacing Carbon Dioxide with Micro Renewables: **Comparing** Technologies

Many UK Planning Authorities now require the use of onsite renewables to reduce the carbon emissions of new developments and major refurbishments. These requirements are usually expressed as a percentage of the 'base case' carbon footprint. Energy efficient design and usage can reduce the base case footprint thereby reducing the absolute requirement for onsite renewables.

However, the challenges of technology selection remain complex and often confusing. This document will help those involved in the design and specification process interpret their carbon target and understand how to identify the most cost effective technology for any given project. The five principal renewable technologies are each appropriate to different circumstances, and can be summarised below.

Solar Photovoltaics: (displace grid electricty)
An exceptionally reliable technology and a strong contributor to carbon reduction. It is the easiest to install, with the lowest maintenance costs. Its versatility makes its deployment appropriate in a wide range of buildings.

Solar Thermal: (displaces heat)
A simple technology with consistent performance that is particularly effective in buildings with large heat demand. However, its potential contribution to CO_2 displacement is limited in buildings where hot water accounts for only a small proportion of the carbon footprint.

Wind: (displaces grid electricty)
Larger installations in rural and coastal locations with high windspeeds offer the most efficient and cost effective carbon displacement available of all the technologies. Microwind in urban locations remains unproven.

Ground Source Heat Pumps: (displace heat)
The requirement for electrical input dramatically reduces this technology's effectiveness in displacing carbon. However, when displacing electricity rather than gas, or when also providing a cooling function, it becomes more effective at displacing CO_2.

Biomass: (displaces heat)
This is best matched to sizeable buildings with a large heat demand, and can potentially offer low cost carbon displacement. The requirements for fuel delivery and onsite storage make it most suitable in larger rural sites. Best suited to organisations that can manage the attendant operation costs and risks.

Carbon Density

CO_2 emissions are the result of energy usage, which is measured in kWh (1kWh = 1 unit of electricity/gas). Each type of energy has a specific density of carbon dioxide associated with it, as defined in Part L 2a of the Building Regulations. The two most common, centrally supplied energy types used in the UK are electricity and gas and when displaced with onsite renewables CO_2 emissions are reduced at the following rates:

- **Electricity = 0.568kg CO_2 Per kWh**
- **Gas = 0.194kg CO_2 Per kWh**

In other words, nearly 3kWh of gas needs to be displaced to create the same CO_2 savings as the displacement of 1kWh of electricity. (It should be noted that, when consumed from the grid, electricity carries a conversion factor of 0.422kg CO_2 per kWh.)

Case Studies

Two example building-types have been used to aid comparison. The annual energy consumption figures use standard official numbers assuming gas is used for heating. We have assumed the target Carbon reduction is 10%.

Domestic Property (90m²)* Annual energy consumption		**Air-conditioned Office (2000m²)** Annual energy consumption**	
Electricity	3,330 kWh	Electricity	256,000 kWh
Heating	14,400 kWh	Heating	164,900 kWh
Hot Water	7,110 kWh	Hot Water	29,100 kWh
Total CO_2	5,578 kg	Total CO_2	145,668 kWh

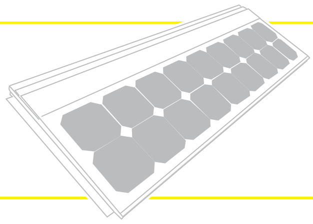
10% Target	**558 kg**	**10% Target**	**14,567 kg**
equals electric	982 kWh	equals electric	25,646 kWh
or gas	2,875 kWh	or gas	75,087 kWh

*UK Digest of Energy Statistics, 2005 DTI UK Average for comparison purposes. Assumes hot water accounts for 33% of fossil fuel requirement. Note that new build projects meeting current building regulations will have a smaller footprint/ target.

**GLA Renewables Toolkit, Faber Maunsell, 2004. Assumes hot water accounts for 15% of fossil requirement.

Installation and maintenance costs are given for PV, Solar Thermal and Wind solutions. For comparison purposes, full lifetime costs are deemed to be those incurred within a 15 year timescale, although typical installations will last considerably longer than this. Legislation and approximate pricing is current for November 2006.

Solar Photovoltaics (PV)



Solar PV converts light into electricity for use within the building and/or for export to the grid. It benefits from being a light-weight simple to fit technology with a very long life and no requirement for expensive engineer maintenance.

Pros

- Simple to install
- Unobtrusive
- No regular maintenance
- Can be integrated into the fabric of the building
- Predictable, consistent yield
- 25 year guarantee (typical), 40-60 year life

Cons

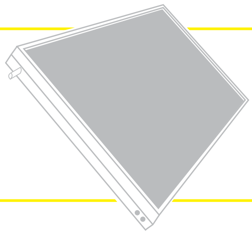
- Requires a south-facing aspect for optimal energy generation
- Shading dramatically reduces generation

Calculations below assume optimally orientated polycrystalline modules producing 810kWh per kWp, sized to meet the 10% carbon target as closely as possible.

Domestic Property		**Office**	
Capacity Requirement:	1.2 kWp	Capacity Requirement:	31.7 kWp
Annual Generation:	982 kWh	Annual Generation:	25,670 kWh
Footprint Displacement:	**10%**	**Footprint Displacement:**	**10%**

Capital Cost:	£7,520	Capital Cost:	£190,200
15 Yr Maintenance Total:	£0	15 Yr Maintenance Total:	£0
Total:	**£7,520**	**Total:**	**£190,200**
Cost per annual kg CO_2:	**£13.47**	**Cost per annual kg CO_2:**	**£13.05**

Solar Thermal



Solar thermal converts energy from the sun into heat energy that can be used to provide a proportion of hot water within the building. It is not recommended for space heating due to the seasonal mismatch, with a low heat load occurring in summer when the equipment is most productive.

A good installation provides between 40-60% of the building's annual hot water requirement, with just the cold winter months preventing the technology from being fully effective all year round.

Pros

- Very effective in buildings with high water usage
- Provides up to 60% of hot water requirement
- Consistent yield, given installation parameters

Cons

- Maintenance: 2-year inspection, 4-year system flush
- Contribution limited to hot water, which sometimes puts 10% CO_2 target out of reach
- Not suitable for space heating (seasonal mismatch)

In order to calculate the amount of gas displaced by a solar thermal system, Ofgem uses a benchmark figure of 396kWh annually per 1m^2 of collector. However, there is no official data available on the performance of solar thermal with different cylinder systems, so actual performance may vary.

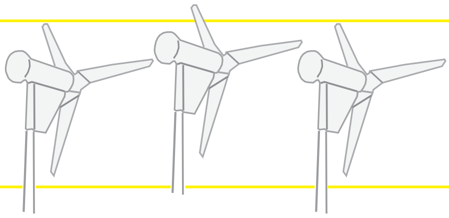
The capacities below have been calculated to match the carbon requirement. Capital costs for both scenarios are for full system installation including cylinder and are based on solarcentury experience of multiple flat plate collector installations.

Domestic Property		**Office**	
Capacity Requirement:	6m^2*	Capacity Requirement:	44m^2
Annual Generation:	2,376kWh	Annual Generation:	17,424kWh
Footprint Displacement:	**8.30%**	**Footprint Displacement:**	**2.3%****

Capital Cost:	£5,000	Capital Cost:	£27,280
15 Yr Maintenance Total:	£1,000	15 Yr Maintenance Total:	£2,400
Total:	**£6,000**	**Total:**	**£29,680**
Cost per annual kg CO_2:	**£13.04**	**Cost per annual kg CO_2:**	**£8.83**

*6m^2 is the standard size installation found in continental Europe. Whilst 6m^2 does not meet the 10% target in the case of the DTI average property as detailed above, it should exceed the target in properties built to current building regulations.
** The maximum that solar thermal can contribute is 60% of the hot water requirement, hence the figures used here (60% x 29,100kWh = 17,460kWh = 3387kg CO_2). In these circumstances, it may be recommended that solar thermal be deployed in conjunction with another technology; on these larger installations, a thermal contribution can lower the cost/kg in a combined thermal and PV solution.

Small Scale Wind



Wind turbines are potentially a very effective technology, but performance is variable and dependent upon local wind conditions, with the smoother, higher-speed airflow usually found in rural and coastal locations being preferred. Performance depends heavily on both windspeed and turbine sizes, with a cubic relationship between rotor diameter and yield (ie, doubling the turbine diameter results in 8 times the energy), and a very steep windspeed/ yield curve.

Pros

- Potential to generate large amounts of electricity at a low cost/kg of CO_2 displaced
- Visible statement of sustainability

Cons

- Maintenance: Annual inspection
- Variable output; unpredictable yield
- Requires smooth airflow and high minimum windspeed to operate optimally
- Planning objections
- Vibration (if building-mounted)
- Noise
- Smaller turbines are less efficient

Audited data from government field trials is not yet available for the smallest domestic turbines so we have used data for medium sized (2.5kWp – 15kWp) turbines instead. For the table below, a windspeed of 4.5m/s is assumed; this is the UK national average and will not usually be achievable in urban locations.

Data used are manufacturers' estimates. Prices are manufacturer's suggested retail prices, including mast upgrades and assume £3000 for foundations for the smaller turbine, and £7000 for foundations on the larger turbine.

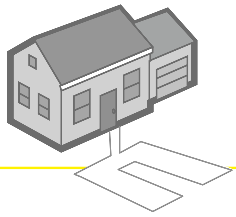
Domestic Property		**Office**	
Capacity Requirement:	2.5kWp*	Capacity Requirement:	30kWp**
Annual Generation:	2500kWh	Annual Generation:	30,000kWh
Footprint Displacement:	**25%**	**Footprint Displacement:**	**11.70%**

Capital cost:	£15,300	Capital cost:	£108,000
15 Yr Maintenance Total:	£3,000	15 Yr Maintenance Total:	£15,000
Total:	**£18,300**	**Total:**	**£123,000**
Cost per annual kg CO_2:	**£12.88**	**Cost per annual kg CO_2:**	**£7.21**

*minimum size turbine we would recommend, with concrete foundation, 3.5m diameter blades and 11m mast

**2 x 15kWp turbine, with concrete foundation, 9m diameter blades and 25m mast

Ground Source Heat Pump



There are several types of geothermal systems. For this comparison we are using a closed-loop Ground Source Heat Pump, which is the most common geothermal technology deployed in the UK. These systems are most efficient when producing the low temperatures required for underfloor heating. A good quality system operating in these circumstances should give a co-efficient of performance of approximately 4. In other words, 1kWh of electricity is used to displace 4kWh of heat.

Part L legislation uses a conversion factor of 0.422 for grid energy used to run a heat pump. This means that 422grams of CO_2 needs to be subtracted from the CO_2 saved by displacing 4kWh of gas. Therefore, the kilograms of CO_2 saved per 4kWh gas displaced can be summarised as follows:

$$\textbf{(4kWh heat x 0.194kg } CO_2\textbf{) – (1kWh electric x 0.422kg } CO^2\textbf{) = 0.354kg } CO_2$$

Therefore an unofficial CO_2 conversion factor for each kWh of gas displaced by GSHP can be calculated thus:

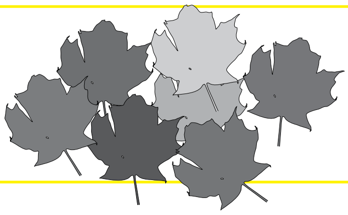
$$\textbf{0.354kg } CO_2 \textbf{ / 4kWh heat = 0.086kg} CO_2 \textbf{ /kWh heat}$$

If our example domestic property were to deploy GSHP to provide for all space heating needs, then the carbon displaced would amount to 1,238kgCO_2, or 22% of total footprint. However, if the office building were to do the same it would fall short of the 10% target, only 14181kg CO_2 or 9.7% of total footprint, due to the large electrical load. solarcentury cannot advise on GSHP costs, so cannot comment on value.

The impact of GSHPs can be much more favourable in the following circumstances:

- In all-electric buildings (where grid electricity is being displaced, instead of gas)
- where the electricity powering the pump is from an onsite renewable source
- where the pump is used to provide cooling in the summer as well as heating in winter

Biomass



There are many types of biomass installation, which often offer very low cost heat generation, so are particularly effective in buildings where there is a large heat requirement, such as leisure centres and hospitals.

Whilst the fuel supply and storage can be troublesome for inner city buildings where there are space limitations, in circumstances where these can be overcome then biomass is often the recommended technology.

However, operating costs and risk need to be taken into consideration when specifying biomass. Both fuel costs and maintenance make operation of a biomass boiler more expensive than any of the other renewable technologies. Meanwhile, the risks of interruption of supply and substandard fuel quality imply extra costs; both in terms of maintenance, and through installation of fossil-fuelled backup boilers. Indeed, the existence of gas boilers sometimes means that the biomass doesn't get used at all.

Conclusion

- Every project has different parameters, and each technology has different strengths
- The different carbon weightings of gas and electricity have a significant impact on the selection of technologies
- The imposition of carbon targets, against which either gas or electricity can be displaced, offers significant flexibility to developers. Achieving the most cost-effective deployment of renewables requires careful consideration

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