Appendix M: Energy from Photovoltaic (PV) technology, small and micro wind turbines and small-scale hydro-electric generators

This appendix may be extended in future to cover other technologies.

M1 Photovoltaics

Photovoltaic technology converts sunlight directly into electricity. It works during daylight hours but more electricity is produced when the sunshine is more intense (a sunny day) and is striking the PV modules directly. Unlike solar systems for heating water, PV technology does not produce heat. Instead, PV produces electricity as a result of interaction of sunlight with semi-conductor materials in the PV cells.

For SAP calculations, the energy produced per year depends on the installed peak power (kWp) of the PV module (the peak power corresponds to the rate of electricity generation in bright sunlight, formally defined as the output of the module under radiation of 1 kW/m² at 25°C). PV modules are available in a range of types and some produce more electricity per square metre than others (the range for currently available types is from about 30 to 125 watts peak per m²), and the peak power depends on the type of module as well as its effective area. In the UK climate, an installation with 1 kWp typically produces about 800 kWh of electricity per year (at favourable orientation and not overshaded).

At times of high solar radiation the PV array may generate more electricity than the instantaneous electricity demand within the dwelling. Arrangements must be made for the surplus electricity to be exported to the grid via a dual or two-way electricity meter.

The procedure for PV is as follows.

1) Establish the installed peak power of the PV unit (kWp).

2) The electricity produced by the PV module in kWh/year is

$$0.8 \times \text{kWp} \times S \times Z_{PV} \qquad \text{(M1)}$$

where S is the annual solar radiation from Table H2 (depending on orientation and pitch), and Z_{PV} is the overshading factor from Table H3.

3) The cost saving associated with the generated electricity depends on whether it is used directly within the dwelling or whether it is exported. Electricity used directly within the dwelling is valued at the unit cost for purchased electricity (usually the standard tariff, or the day rate in the case of an off-peak tariff). Electricity exported is valued at the price for electricity sold to the grid.
The effective price depends on a factor β, which is in the range 0.0 to 1.0 and is defined as the proportion of the generated electricity that is used directly within the dwelling. The value of β depends on the coincidence of electricity generation and electricity demand within the dwelling. At present the value of β = 0.50 should be used for SAP calculations: this will be reviewed in future if relevant data becomes available.
The fuel price used in the calculation of box (95a) is:
$\beta \times$ normal electricity price + $(1 - \beta) \times$ exported electricity price.

4) For calculation of CO_2 emissions, the emissions factor for grid-displaced electricity from Table 12 is used in the calculation of box (110). The same factor applies to all electricity generated, whether used within the dwelling or exported.

5) Where the PV array is mounted on the building concerned or wholly within its curtilage, and its output is directly connected to the building's electricity supply, the output calculated by (M1) is entered in the worksheet at box (95).

6) In other cases the output calculated by (M1) divided by the total floor area of buildings on the development may be entered in (ZC6), see Section 14, when the total net CO_2 emissions are being calculated.

M2 Micro wind turbines on the building or within its curtilage

The procedure given below applies to small wind turbines mounted either on the roof of the dwelling or on a nearby mast within its curtilage. For other cases see M3.

The performance of wind turbines is very sensitive to the local wind conditions. The procedure is based on typical conditions using a formula given by GreenSpec [*] and the wind speed correction factors given in MIS 3003 [†].

At times of higher wind speeds the wind turbine may generate more electricity than the instantaneous electricity demand within the dwelling. Arrangements must be made for the surplus electricity to be exported to the grid via a dual or two-way electricity meter.

It should be noted that the procedure given in this Appendix is an approximate one and in particular that the correction factors in MIS 3003, while representing the best currently available estimates, are known to be imprecise. Also, it is based on generic turbine technology. It will be revised as better information becomes available.

Meanwhile the procedure is considered as valid for the purposes of calculations by SAP 2005 when:
- no part of the turbine blade dips below the level of the ridge of the roof;
- there are no obstructions significantly larger than the building within a radius of 10 times the building height.

It should not be applied if those conditions are not met.

1) The output power P_{wind} of one turbine in watts at a wind speed of s m/s is:

$$P_{wind} = CP \times A \times PA \times G \times IE \qquad \text{(M2)}$$

where
CP is the aerodynamic power coefficient (efficiency of the rotor to convert energy)
A is the swept area of the blade
PA is the power density of the wind = $0.6125\ s^3$
G is the efficiency of the generator
IE is efficiency of the inverter (allowing for power drawn by the inverter) [‡].

2) The annual energy in kWh/year is related to the output at average wind speed by

$$E_{wind} = N_{turbines} \times P_{wind} \times 1.9 \times 8766 \times 0.001 \qquad \text{(M3)}$$

where $N_{turbines}$ is the number of wind turbines, 1.9 is a parameter representing the wind speed variation function and 8766 is the average number of hours per year.

3) The product of CP, G and IE is taken as 0.24.

4) The area A is $0.25 \times \pi \times (\text{rotor diameter})^2$.

[*] www.greenspec.co.uk/html/energy/windturbines.html (accessed 20 September 2007)
[†] Microgeneration Installation Standard MIS 3003, *Requirements for contractors undertaking the supply, design, installation, set to work commissioning and handover of micro and small wind turbine systems*, BRE Certification Ltd, 2007, http://www.redbooklive.com/page.jsp?id=135 (accessed 20 September 2007)
[‡] Equation (M2) differs from that on the GreenSpec website by including IE. The latter is included so as to provide the system output rather than the turbine output.

5) The average wind speed is taken as 5.0 m/s multiplied by the appropriate correction factor from Table M1 [*].

6) The total electricity produced as calculated in step 2) above is entered in box (95) of the worksheet.

7) For calculation of the cost savings the factor β (see Section M1) is 0.7.

8) For calculation of CO_2 emissions, the emissions factor for grid-displaced electricity from Table 12 applies to all electricity generated, whether used within the dwelling or exported.

Table M1 : Wind speed correction factors

Terrain type	**Height of turbine hub above ridge of roof (m)***	**Correction factor**
Dense urban (city centres with mostly closely spaced buildings of four storeys or higher)	10	0.56
	5	0.51
	2	0.40
	0	0.28
Low rise urban / suburban (town or village situations with other buildings well spaced)	6	0.67
	4	0.61
	2	0.53
	0	0.39
Rural (open country with occasional houses and trees)	12	1.00
	7	0.94
	2	0.86
	0	0.82

* must be at least half the rotor diameter

Use linear interpolation for intermediate values. For hub height higher than the maximum given for the terrain type use the highest for that terrain type (i.e. 0.56, 0.67 or 1.00). This is because of limitations of current knowledge; the table will be revised in future.

M3 Wind turbines associated with more than one dwelling

This refers to wind turbines such as might be installed as part of a housing development. They are not included for the assessment of ratings but can be included in the assessment of an overall CO_2 emission figure inclusive of energy uses (including appliances and cooking), see Section 14. If not actually on the site they can be included provided that they are connected to the site via private wires. Electricity surplus to the instantaneous electricity demand of the dwellings is fed into the electricity grid.

The total annual output of wind turbines should be estimated using the procedure given in Microgeneration Installation Standard MIS 3003. It is recommended that the wind speed at the intended location is monitored for at least a year in order ascertain the local wind conditions but if that data is not available the wind speed can be estimated from the NOABL database as described in MIS 3003 (this is subject to the limitation in MIS 3003 of a maximum 50 kW rated output at a wind speed of 11 m/s).

[*] Factors in Table M1 derived from data in *The Designer's Guide to Wind Loading of Structures*, N.J. Cook, Butterworths, 1986

The output from the wind turbines should be apportioned between the dwellings concerned on the basis of their floor area, by dividing the total annual output by the total floor area of buildings on the development, and entered in kWh/m² into box (ZC6) in Section 14.

M4 Small-scale hydro-electric generators

Hydro-electric generation is possible only in a small number of situations. Each case is different and detailed calculations of the electricity generated are outside the scope of SAP 2005.

Where small-scale hydro-electric generation is applicable, it may be allowed for in SAP calculations as follows.

1) The total electricity generated per year is calculated and signed off by a suitably qualified engineer having adequate competence in the assessment of the technology. In case of doubt guidance should be sought from BRE.
2) Where more than one dwelling benefits from the hydro-electric generation, the kWh per year attributable to each dwelling is obtained from the total in step 1) apportioned to each dwelling according to the total floor area of the dwelling.
3) For calculation of the cost savings the factor β (see Section M1) is 0.4.
4) For calculation of CO_2 emissions, the emissions factor for grid-displaced electricity from Table 12 applies to all electricity generated, whether used within the dwelling or exported.
5) Where the electricity generator is within the curtilage of the building, and its output is directly connected to the building's electricity supply, the output is entered in the worksheet at box (95).
6) In other cases the electricity generated divided by the sum of the floor areas of the buildings concerned may be entered in (ZC6), see Section 14, when the total net CO_2 emissions are being calculated.