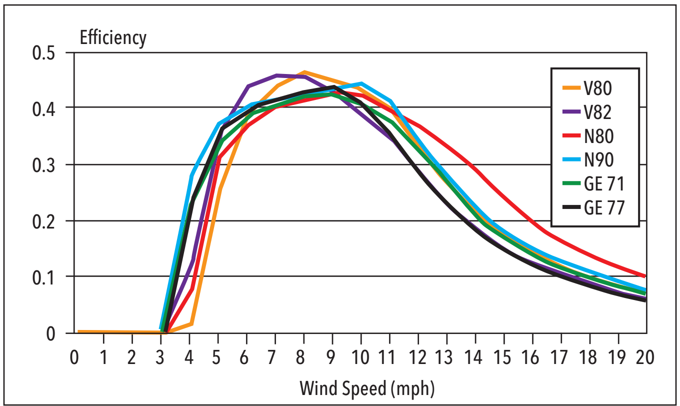

Figure 11-3. Efficiency of selected large wind turbines. Conversion efficiency of large wind turbines relative to the power in wind at the specified instantaneous wind speed. Efficiency was calculated from publicly available power curves assembled by the Idaho National Engineering Laboratory in 2007 of turbines commonly available in the early to mid-2000s. These include Vestas's V80 and V82, Nordex's N80 and N90, and General Electric's 1500 (71 meter) and 1500sl (77 meter) turbines. Note that large wind turbines are nearly twice as efficient as micro and mini wind turbines.

Compare the annual specific yield in Table 11-2 with that in Table 11-1 for an average annual wind speed of 6 m/s: 400 W/m² to 580 W/m². The new, high-performance household-size turbines are nearly 50% more efficient at capturing the energy in the wind than those wind turbines available in the 1990s represented in Table 11-1.

Where certified power curves and AEP estimates are unavailable, it's wise to use the conservative specific yields in Table 11-1. Some small wind turbines deliver even less than the values in Table 11-1. After all, the specific yields in Table 11-1 represent an average. Some small turbines perform better, some worse than the average.

Large Wind Turbines

Large wind turbines are considerably more efficient at extracting the energy in the wind at a specific instantaneous wind speed than small wind turbines (see Figure 11-3. Efficiency of selected large wind turbines). Large wind turbines are nearly twice as efficient as the micro and mini wind turbines of the 1990s and as much as one-third more efficient than the newer, high-performance household-size wind turbines now available (see Table 11-3. Estimated Annual Energy Production for Large Wind Turbines).

We can apply the same method used to estimate the annual energy production for large wind turbines as we did for small wind turbines. In the earlier example of our hypothetical 80-meter-diameter wind turbine, we assumed that the turbine could convert 30% of the energy in the wind throughout the year at an average annual wind speed of 7 m/s (15.7 mph). This is typical of most wind turbines of this size on the market in the early to mid-2000s as seen in Table 11-3.

Table 11-3. Estimated Annual Energy Production for Large Wind Turbines

Average Annual Wind Speed		Power Density	Total Efficiency	Average Annual Specific Yield
m/s	~mph	W/m²	η	kWh/m²/yr
4.0	9.0	75	0.37	240
4.5	10.1	107	0.38	350
5.0	11.2	146	0.38	480
5.5	12.3	195	0.37	620
6.0	13.4	253	0.35	770
6.5	14.6	321	0.33	920
7.0	15.7	401	0.30	1,060
7.5	16.8	494	0.28	1,200
8	17.9	599	0.25	1,330
8.5	19.0	718	0.23	1,460
9	20.2	853	0.21	1,570

Note: Gross generation for a single turbine at hub-height wind speed, based on published manufacturer's data for selected models typical of the early to mid-2000s. This table does not take into account IEC classes. Actual performance may vary.

Using this example, we can estimate the annual energy production from Table 11-3.

AEP = Average Annual Specific Yield x Swept Area

AEP = 1,060 kWh/m²/yr x ~ 5,000 m² =
5,300,000 kWh/yr.

This calculation can be even simpler for a quick estimate of what an 80-meter diameter turbine can do at this site. We know, for example, that at an average annual hub-height wind speed of 7 m/s, the typical specific yield is about 1,000 kWh/m²/yr, and we know that an 80-meter diameter wind turbine sweeps about 5,000 m². Therefore,

AEP ~1,000 kWh/²/yr x ~5,000 m² =
~ 5,000,000 kWh/yr.

To reiterate, to quickly estimate the AEP of a large wind turbine, find the average annual specific yield in kWh/m²/yr for the conditions at the site and multiply the result by the rotor swept area.