

Renewable and Efficient Electric Power Systems | (0th Edition)

Step-by-step solution

Step 1 of 11

The capacity factor correlation,

$$CF = 0.087\bar{v} - \frac{P_g}{D^3}$$

CF is capacity factor correlation.

$\bar{v}$ is average wind speed in m/s.

P_g is rated power in kW

D is diameter in m.

The annual electricity produced,

$$\text{annual energy} = P_g (\text{kW}) \times 8760 \text{ h/yr} \times CF$$

P_g is rated power in kW and CF is capacity factor.

The annual debt payments on the loan,

$$A = P \left[\frac{i(1+i)^n}{(1+i)^n - 1} \right]$$

A is annual payments in (\$/yr). P is the principle in (\$), i is the interest rate, and n is loan term in years.

The annual return on equity needs is,

$$\text{equity} = \text{equity/yr} \times \text{capital cost} (\$)$$

The annual operational and maintenance needs,

$$O\&M = \frac{O\&M\%}{100} \times \text{capital cost} (\$)$$

Annual cost for O&M, debt, and equity is,

$$\text{annual cost} = (O\&M + \text{equity} + \text{debt}) \$$$

The leveled cost of electricity is,

$$LCOE = \frac{\text{annual cost}}{\text{annual energy}}$$

Step 2 of 11

(a)

Principle amount is,

$$P = (1500 \text{ kW}) \times (800 \$/\text{kW}) \\ = \$1,200,000$$

The capacity factor is,

$$CF = 0.087\bar{v} - \frac{P_g}{D^3}$$

Substitute 8.5 m/s for $\bar{v}$, 1500 kW for P_g , and 64 m for D.

$$CF = 0.087(8.5 \text{ m/s}) - \frac{(1500 \text{ kW})}{(64 \text{ m})^3} \\ = 0.3733$$

Step 3 of 11

The annual electricity produced,

$$\text{annual energy} = P_g (\text{kW}) \times 8760 \text{ h/yr} \times CF$$

Substitute 1500 kW for P_g , and 0.3733 for C.F.

$$\text{annual energy} = 1500 \text{ kW} \times 8760 \text{ h/yr} \times 0.3733 \\ = 4,905,162 \text{ kWh/yr}$$

The annual debt payments,

$$A = P \left[\frac{i(1+i)^n}{(1+i)^n - 1} \right]$$

Substitute \$1,200,000 for P, 0.07 for i, and 20 for n.

$$A = (\$1,200,000) \left[\frac{0.07(1+0.07)^{20}}{(1+0.07)^{20} - 1} \right] \\ = \$113,238.93 / \text{yr}$$

Step 4 of 11

The annual return on equity,

$$\text{equity} = 0.15 / \text{yr} \times \frac{25}{100} \times (\$1,200,000) \\ = 0.15 / \text{yr} \times \$300,000 \\ = \$45,000 / \text{yr}$$

The annual operational and maintenance needs,

$$O\&M = \frac{3}{100} / \text{yr} \times (\$1,200,000) \\ = \$36,000 / \text{yr}$$

Annual cost for O&M, debt, and equity,

$$\text{annual cost} = \$ (113,239 + 45,000 + 36,000) / \text{yr} \\ = \$194,239 / \text{yr}$$

The leveled cost of electricity is,

$$LCOE = \frac{\text{annual cost}}{\text{annual energy}}$$

Step 5 of 11

Substitute \$194,239/yr for annual cost, and 4,905,162 kWh/yr for annual energy.

$$LCOE = \frac{\$194,239 / \text{yr}}{4,905,162 \text{ kWh/yr}} \\ = \$0.0395 \\ = 3.95 \text{ ¢/kWh}$$

Thus, the leveled cost of electricity, $LCOE = 3.95 \text{ ¢/kWh}$

Step 6 of 11

(b)

Principle amount,

$$P = (600 \text{ kW}) \times (1000 \$/\text{kW}) \\ = \$600,000$$

The capacity factor,

$$CF = 0.087\bar{v} - \frac{P_g}{D^3}$$

Substitute 8.5 m/s for $\bar{v}$, 600 kW for P_g , and 42 m for D.

$$CF = 0.087(8.5 \text{ m/s}) - \frac{(600 \text{ kW})}{(42 \text{ m})^3} \\ = 0.3994$$

The annual electricity produced,

$$\text{annual energy} = P_g (\text{kW}) \times 8760 \text{ h/yr} \times CF$$

Substitute 600 kW for P_g , and 0.3994 for C.F.

$$\text{annual energy} = 600 \text{ kW} \times 8760 \text{ h/yr} \times 0.3994 \\ = 2,099,246.4 \text{ kWh/yr}$$

The annual debt payments,

$$A = P \left[\frac{i(1+i)^n}{(1+i)^n - 1} \right]$$

Substitute \$600,000 for P, 0.07 for i, and 20 for n.

$$A = (\$600,000) \left[\frac{0.07(1+0.07)^{20}}{(1+0.07)^{20} - 1} \right] \\ = \$56,634 / \text{yr}$$

The annual return on equity,

$$\text{equity} = 0.15 / \text{yr} \times \frac{25}{100} \times (\$600,000) \\ = 0.15 / \text{yr} \times \$150,000 \\ = \$22,500 / \text{yr}$$

The annual operational and maintenance needs,

$$O\&M = \frac{3}{100} / \text{yr} \times (\$600,000) \\ = \$18,000 / \text{yr}$$

Annual cost for O&M, debt, and equity,

$$\text{annual cost} = \$ (56,634 + 22,500 + 18,000) / \text{yr} \\ = \$97,134 / \text{yr}$$

The leveled cost of electricity,

$$LCOE = \frac{\text{annual cost}}{\text{annual energy}}$$

Substitute \$97,134/yr for annual cost, and 2,099,246.4 kWh/yr for annual energy.

$$LCOE = \frac{\$97,134 / \text{yr}}{2,099,246.4 \text{ kWh/yr}} \\ = \$0.0463 \\ = 4.63 \text{ ¢/kWh}$$

Thus, the leveled cost of electricity, $LCOE = 4.63 \text{ ¢/kWh}$

Step 7 of 11

(c)

Principle amount,

$$P = (250 \text{ kW}) \times (1200 \$/\text{kW}) \\ = \$300,000$$

The capacity factor,

$$CF = 0.087\bar{v} - \frac{P_g}{D^3}$$

Substitute 8.5 m/s for $\bar{v}$, 250 kW for P_g , and 29.2 m for D.

$$CF = 0.087(8.5 \text{ m/s}) - \frac{(250 \text{ kW})}{(29.2 \text{ m})^3} \\ = 0.4463$$

The annual electricity produced,

$$\text{annual energy} = P_g (\text{kW}) \times 8760 \text{ h/yr} \times C.F$$

Substitute 250 kW for P_g , and 0.4463 for C.F.

$$\text{annual energy} = 250 \text{ kW} \times 8760 \text{ h/yr} \times 0.4463 \\ = 977,397 \text{ kWh/yr}$$

The annual debt payments,

$$A = P \left[\frac{i(1+i)^n}{(1+i)^n - 1} \right]$$

Substitute \$300,000 for P, 0.07 for i, and 20 for n.

$$A = (\$300,000) \left[\frac{0.07(1+0.07)^{20}}{(1+0.07)^{20} - 1} \right] \\ = \$28,317 / \text{yr}$$

The annual return on equity,

$$\text{equity} = 0.15 / \text{yr} \times \frac{25}{100} \times (\$300,000) \\ = 0.15 / \text{yr} \times \$75,000 \\ = \$11,250 / \text{yr}$$

Step 8 of 11

The annual operational and maintenance needs,

$$O\&M = \frac{3}{100} / \text{yr} \times (\$300,000) \\ = \$9,000 / \text{yr}$$

Annual cost for O&M, debt, and equity,

$$\text{annual cost} = \$ (28,317 + 11,250 + 9,000) / \text{yr} \\ = \$48,567 / \text{yr}$$

The leveled cost of electricity,

$$LCOE = \frac{\text{annual cost}}{\text{annual energy}}$$

Substitute \$48,567/yr for annual cost, and 977,397 kWh/yr for annual energy.

$$LCOE = \frac{\$48,567 / \text{yr}}{977,397 \text{ kWh/yr}} \\ = \$0.0497 \\ = 4.97 \text{ ¢/kWh}$$

Thus, the leveled cost of electricity, $LCOE = 4.97 \text{ ¢/kWh}$

Step 9 of 11

(d)

Principle amount,

$$P = (1000 \text{ kW}) \times (900 \$/\text{kW}) \\ = \$900,000$$

The capacity factor,

$$CF = 0.087\bar{v} - \frac{P_g}{D^3}$$

Substitute 8.5 m/s for $\bar{v}$, 1000 kW for P_g , and 60 m for D.

$$CF = 0.087(8.5 \text{ m/s}) - \frac{(1000 \text{ kW})}{(60 \text{ m})^3} \\ = 0.4617$$

The annual electricity produced,

$$\text{annual energy} = P_g (\text{kW}) \times 8760 \text{ h/yr} \times CF$$

Substitute 1000 kW for P_g , and 0.4617 for CF.

$$\text{annual energy} = 1000 \text{ kW} \times 8760 \text{ h/yr} \times 0.4617 \\ = 4044686.66 \text{ kWh/yr}$$

Step 10 of 11

The annual debt payments is,

$$A = P \left[\frac{i(1+i)^n}{(1+i)^n - 1} \right]$$

Substitute \$900,000 for P, 0.07 for i, and 20 for n.

$$A = (\$900,000) \left[\frac{0.07(1+0.07)^{20}}{(1+0.07)^{20} - 1} \right] \\ = \$84951 / \text{yr}$$

The annual return on equity is,

$$\text{equity} = 0.15 / \text{yr} \times \frac{25}{100} \times (\$900,000) \\ = 0.15 / \text{yr} \times \$225,000 \\ = \$33,750 / \text{yr}$$

The annual operational and maintenance needs is,

$$O\&M = \frac{3}{100} / \text{yr} \times (\$900,000) \\ = \$27,000 / \text{yr}$$

Step 11 of 11

Annual cost for O&M, debt, and equity,

$$\text{annual cost} = \$ (84,951 + 33,750 + 27,000) / \text{yr} \\ = \$145,701 / \text{yr}$$

The leveled cost of electricity,

$$LCOE = \frac{\text{annual cost}}{\text{annual energy}}$$

Substitute \$145,701/yr for annual cost, and 4044686.66 kWh/yr for annual energy.

$$LCOE = \frac{\$145,701 / \text{yr}}{4044686.66 \text{ kWh/yr}} \\ = \$0.036 \\ = 3.6 \text{ ¢/kWh}$$

Thus, the leveled cost of electricity is $LCOE = 3.6 \text{ ¢/kWh}$

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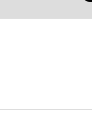
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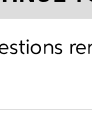
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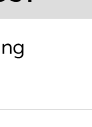
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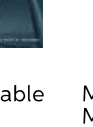
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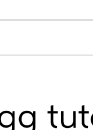
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