7.13 The 2013 “low wind” turbine pricing in Table 7.6 uses a 1.62 MW turbine with an installed cost of $2025/kW with a 100-m rotor diameter.

a. At a site with 6 m/s Rayleigh winds at 50-m, estimate the energy this turbine would deliver at a hub height of 100 m assuming the usual 1/7th wind-shear factor. Assume 15% losses.

b. Assuming a nominal 9% financing charge with a 20-year term along with annual O&M costs of $60/kW, find the levelized cost of electricity. Does it agree with Figure 7.48?

Table 7.6

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>2002</th>
<th>2009</th>
<th>2013 Turbine Pricing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power (MW)</td>
<td>1.5</td>
<td>1.5</td>
<td>1.62</td>
</tr>
<tr>
<td>Hub height (m)</td>
<td>65</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Rotor diameter (m)</td>
<td>71.5</td>
<td>77</td>
<td>82.5</td>
</tr>
<tr>
<td>Installed capital cost (MkW)</td>
<td>1390</td>
<td>2150</td>
<td>1600</td>
</tr>
<tr>
<td>Operating and (M/kW/hr)</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Lashes (%)</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Financing (interest) (%)</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
</tbody>
</table>

Eqn 7.62:

\[ V = V_0 \left( \frac{H}{H_0} \right)^x = 6 \left( \frac{100}{50} \right)^{\frac{1}{7}} = 6.62 \text{ m/s} \]

\[ X = \text{WIND SHEAR FACTOR} \]
\[ H_0 = 50 \text{ m}; \ H = 100 \text{ m} \]

\[ \text{CF} = \frac{\text{ENERGY DELIVERED}}{\text{ENERGY PER kW}} \]
\[ = \frac{0.87 (J)}{0.87 \left(6.62^2\right)} = \frac{1620}{(600^2)} = 0.443 \]

\[ E = \text{CF}(1-\text{losses}) \times 8760, \ P_R = 0.443 \times (1-15) \times 8760 \times 1620 \]

\[ = 4.997 \times 10^6 \text{ kwh} \]

\[ \text{EXPECTED ENERGY DELIVERED PER YEAR} \]

\[ A = \text{ANNUAL PAYMENTS} = CRF(\alpha, n) \times P \]

\[ \text{CRF}(\alpha, n) = \frac{i(1+i)^n}{(1+i)^n-1} = \frac{0.09(1.09)^{20}}{(1.09)^{20}-1} = 1.095 \]

\[ A = 1.095 \times 2025/6/kW \times 1620 \text{ kW} = 359,367 \text{ k} \]
LCOE (LEVELIZED COST OF ENERGY) = \( \frac{\text{ANNUAL FIXED COST} + \text{ANNUAL VARIABLE COST}}{\text{ANNUAL OUTPUT}} \)

Operating cost ($/kWh) = $60/\text{kWh} \cdot 1620 = $97,200

LCOE = \( \frac{357,367 + 97,200}{4,999 \times 10^6} \) = $0.09748/kWh

This LCOE does agree w/ P163.48 (at 6 m/s, 50 m)

Ans.
A wind turbine with a capital cost of $3 million delivers 5 million kWh/yr. Assuming a 35% corporate tax rate and a nominal 9% discount factor find the following:

a. The present value of the 5-year MACRS depreciation assuming it starts at the end of the first year of operation.

b. The present value of the production tax credit (PTC) assuming a 10-year PTC at a fixed 2.2¢/kWh first paid at the end of the initial year of operation.

c. What is the net capital cost if we subtract the present values of its MACRS and PTC payments?

d. Assuming the above net cost is amortized using a 20-year, 9% CRF, what is the levelized cost of electricity for this turbine? Compare it to the LCOE without MACRS and PTC.

### MASTERS 2d Ed Prob 7.14

<table>
<thead>
<tr>
<th>Year</th>
<th>MACRS: (fixed by tax code)</th>
<th>Depreciation(§): (MACRS*Syscost(§))</th>
<th>Depreciation tax savings: Depreciation(§)*Corp tax rate</th>
<th>Present Value of Tax Savings: PV = DepTaxSavings*(1+ CorpDiscRate)^-year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20.0000%</td>
<td>$600,000.00</td>
<td>$210,000.00</td>
<td>$192,660.55</td>
</tr>
<tr>
<td>2</td>
<td>32.0000%</td>
<td>$960,000.00</td>
<td>$336,000.00</td>
<td>$282,804.48</td>
</tr>
<tr>
<td>3</td>
<td>19.2000%</td>
<td>$576,000.00</td>
<td>$201,600.00</td>
<td>$155,672.19</td>
</tr>
<tr>
<td>4</td>
<td>11.5200%</td>
<td>$345,600.00</td>
<td>$120,960.00</td>
<td>$85,691.11</td>
</tr>
<tr>
<td>5</td>
<td>11.5200%</td>
<td>$345,600.00</td>
<td>$120,960.00</td>
<td>$78,615.70</td>
</tr>
<tr>
<td>6</td>
<td>5.7600%</td>
<td>$172,800.00</td>
<td>$60,480.00</td>
<td>$36,062.25</td>
</tr>
</tbody>
</table>

a) Present Year Value TOTAL $831,506.28

<table>
<thead>
<tr>
<th>Year</th>
<th>Production Tax Credit</th>
<th>Tax Savings PV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$110,000.00</td>
<td>$100,917.43</td>
</tr>
<tr>
<td>2</td>
<td>$110,000.00</td>
<td>$92,584.80</td>
</tr>
<tr>
<td>3</td>
<td>$110,000.00</td>
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<tr>
<td>5</td>
<td>$110,000.00</td>
<td>$71,492.45</td>
</tr>
<tr>
<td>6</td>
<td>$110,000.00</td>
<td>$65,589.41</td>
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<tr>
<td>7</td>
<td>$110,000.00</td>
<td>$60,173.77</td>
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<tr>
<td>8</td>
<td>$110,000.00</td>
<td>$55,205.29</td>
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<tr>
<td>9</td>
<td>$110,000.00</td>
<td>$50,647.06</td>
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<tr>
<td>10</td>
<td>$110,000.00</td>
<td>$46,465.19</td>
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</tbody>
</table>

b) Tax Savings TOTAL: $705,942.35

\[ PV = PTC^* (1+ CorpDiscRate)^-year \]

\[ \text{Tax Savings PV} = 705,942.35 \]

\[ \text{Annual kWh Generated} \quad 5,000,000 \]

\[ \text{Production Tax Credit} \quad 0.0220 \quad \text{per kWh} \]

\[ \text{Production Tax Credit} \quad 110,000.00 \]

\[ \text{Tax Savings PV} \quad 705,942.35 \]

\[ \text{Present Value of Tax Savings} \quad 831,506.28 \]

\[ \text{Present Value of Tax Savings} \quad 705,942.35 \]

\[ \text{Net capital cost} \quad 1,462,551.37 \]

20 Year amortization

\[ \text{Capital Recovery Factor} = \left( \frac{1}{(1+i)^n} \right) - 1 \]

\[ = 0.109546475 \]

With MCRS and PTC

\[ \text{LCOE} = \frac{\text{Annual Cost/Annual Energy production}}{\text{per kWh}} \]

\[ = 0.052 \quad \text{per kWh} \]

Without MCRS and PTC

\[ \text{LCOE} = \frac{0.0657}{\text{per kWh}} \]
1. The cost of fuel for a small power plant is currently $10,000 per year. The owner's discount rate is 12% and fuel is projected to increase at 6% per year over the 30-yr life of the plant. What is the levelized cost of fuel?

\[
\text{Cost} = C = 6\% \text{ ESCALATION RATE} \\
\gamma = 30 \\
\delta = 12\% \\
d' = \frac{(d-e)}{(1+e)} = \frac{12-0.06}{(1+0.06)} = 0.06 = 0.566
\]

\[
\text{LEVELIZED COSTS} = \frac{PVF(d',\gamma) \cdot CRF(d,\gamma)}{}
\]

\[
PVF(d',\gamma) = \frac{(1+d')^{\gamma} - 1}{d'[(1+d')^\gamma]} = \frac{(1+0.06)^{30} - 1}{0.06(1+0.06)^{30}} = 14.28
\]

\[
CRF(d,\gamma) = \frac{d(1+d)^\gamma}{(1+d)^\gamma - 1} = \frac{12(1.12)^{30}}{(1.12)^{30} - 1} = 1.241
\]

\[
\text{LEVELIZED COST} = 10,000 \times (14.28)(1.241)
\]

\[
= \$17,727 \text{ Y/Y}
\]

ANS.

COMPARED TO $10,000 ANNUAL 
FUE COST U INFLATION.

6\% ANNUAL INFLATION OVER 30 YEARS

A005 SIGNIFICANT FUEL COST.
2. Better windows for a building adds $3/ft^2$ of window but saves $0.55/ft^2$ per year in reduced heating, cooling and lighting costs. With a 12% discount rate:
   a. What is the net present value (NPV) of the better windows over a 30-year period with no escalation in the value of the annual savings?
   b. What is the internal rate of return (IRR) with no escalation rate?
   c. What is the NPV if the savings escalates at 7%/yr due to fuel savings?
   d. What is the IRR with that fuel escalation rate?

\[
\text{a)} \quad \text{NPV} = \Delta A \times PVF(d, n) - \Delta P
\]

\[
PVF(d, n) = \frac{(1+d)^n - 1}{d(1+d)^n} = \frac{(1+12)^{30} - 1}{12(1+12)^{30}} = 8.055
\]

\[
\text{NPV} = 8.55 (8.055) - 8 \times 3 = \$143
\]

\[
\text{b)} \quad \text{IRR} \quad \text{from Table A.1 with } \frac{\Delta P}{\Delta A} = 1.6 = 5.45\%
\]

<table>
<thead>
<tr>
<th>Life (yr)</th>
<th>3%</th>
<th>4%</th>
<th>5%</th>
<th>6%</th>
<th>7%</th>
<th>8%</th>
<th>9%</th>
<th>10%</th>
<th>11%</th>
<th>12%</th>
<th>13%</th>
<th>14%</th>
<th>15%</th>
<th>16%</th>
<th>18%</th>
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<td>11.08</td>
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<td>10.87</td>
<td>10.78</td>
<td>10.69</td>
<td>10.60</td>
<td>10.51</td>
<td>10.41</td>
<td></td>
</tr>
</tbody>
</table>

\[
\text{IRR} = 18.5\% \quad \text{ANS}
\]

\[
\Delta P = 5.45
\]

\[
\text{c)} \quad \text{NPV} = \Delta A \times PVF(d', n) - \Delta P \quad \text{with } \frac{\Delta P}{\Delta A} = \frac{d'-e}{h/e} = \frac{12-0.02}{1+(0.07)}
\]

\[
PVF(d', n) = \frac{(1+d')^n - 1}{d'(1+d')}
\]

\[
d' = 0.06
\]
c) (cont)

\[ PVF (d', n) = \frac{(1 + 0.06)^3 - 1}{0.06 (1 + 0.06)^3} = 16.098 \]

\[ NPV = (55)(16.098) - 3 \]

\[ = \$ 5,847 \]

\[ \text{ANS.} \]

d) \[ IRR_e = IRR_0 (1 + e) + e = 0.18 (1 + 0.07) + 0.07 \]

\[ = 26.3\% \]

\[ \text{ANS.} \]