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SUSTAINABLE ENERGY

Spring 2005

HOMEWORK #3: ECONOMIC AND RESOURCE ANALYSIS

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1. Using the class notes and relevant chapters from the textbook we wish to evaluate factors of economic performance of different electricity generation proposals. Please assume reasonable values for any necessary but unspecified problem parameters.

   A. Which of the follow two power plant concepts is economically more attractive?

a) A coal-fired power station for which the following data apply:

• Specific capital costs	= 1,500 \$/kWe
• Interest rate	= 0.07 yr^{-1}
• Inflation rate	= 0.03 yr^{-1}
• Taxation rate	= 0.02 yr^{-1}
• Capacity factor	= 0.90
• Thermal efficiency	= 0.40
• Service lifetime	= 50 yr
• Fuel cost	= 0.005 \$/kWhrt
• Operations cost	= 50×10^{6} \$/yr
• Peak power generation capacity	= 1,000 MWe

b) A solar-power photovoltaic station for which the following data apply:

• Peak power generation capacity	= 1,000 MWe
• Peak solar energy flux	= 400 kW/m^2
• Solar collector specific cost	= 1,000 $\$/m^2$
• Power conversion efficiency (converting solar energy into electricity)	= 0.10
• Capacity factor	= 0.15
• Service lifetime	= 30 yr
• Operations cost	= 50×10^{6} \$/yr
• Interest, inflation and taxation rates are the same with the coal-fired plant	

In comparing these concepts do this on the basis:

i. The annual average costs of electricity produced, and
ii. The costs of electricity produced under their respectively most favorable conditions.

B. For the coal-fired power plant assume that the economics of scale reflect an $n = 2/3$ exponential dependence upon the plant capacity. How would the specific capital costs of a 500 MWe plant compare to those of a 1,000 MWe one?

C. Using data concerning the economies of mass production (also termed serial production, or learning effects), how would the capital cost of the 1-million-th solar collector compare to that of the first?

2. Consider an electric power grid having three generating stations:

- A coal-fired unit of 1,000 MWe capacity and electricity production cost of 3.0 ¢/kWhre.
- An oil-fired unit of 500 MWe capacity and electricity production costs of 5.0 ¢/kWhre.
- A wind-powered unit of 200 MWe maximum capacity that operates in the generation, G, range $20 < G \leq 200$ MWe. The probability density function of the plant's output, G, reflecting variations in wind conditions is as shown in Fig. 1, or

$$f(G) = \begin{cases} \frac{1}{180}\,\text{MWe}^{-1}, & 20 < G < 200\ \text{MWe, and} \\ 0, & \text{otherwise.} \end{cases}$$

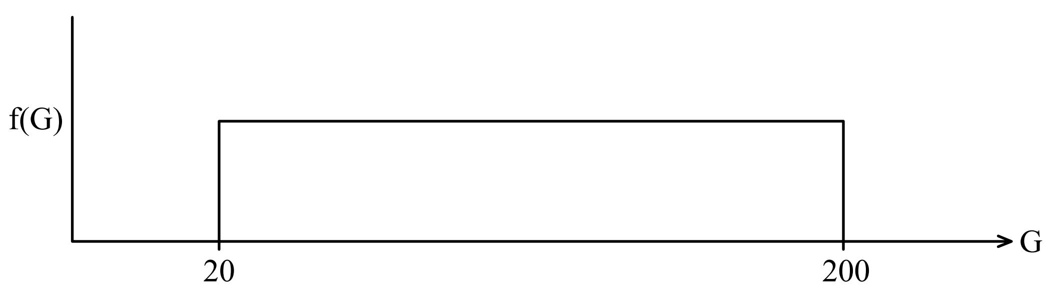

Figure 1. Probability density function for wind-powered plant output, G = Units of MWe.

Also, demand for electricity, D, obeys a triangular probability distribution as shown in Fig. 2.

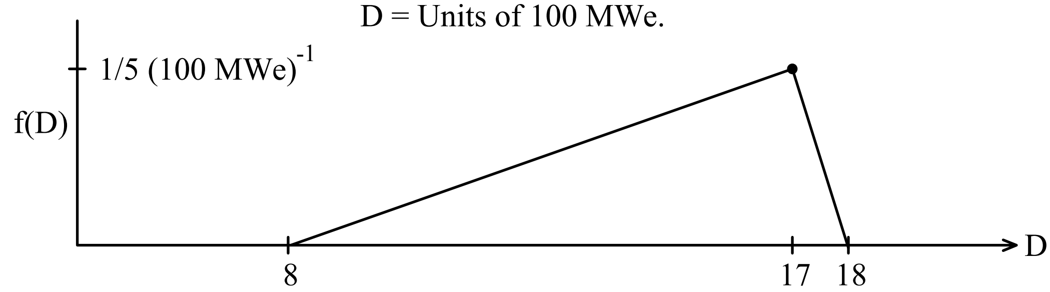

Figure 2. Probability density function for total demand, D.

A. What is the probability that the grid will be unable to meet the demand if it is at full capacity (assume that G and D are independent variables)? How might G and D actually be mutually dependent?

B. What is the cost of electricity when the grid is meeting the expected demand level, $\overline{D}$?

Notes: $1 = \int_{D_{min}}^{D_{max}} f(D)dD$ (Normalization)

$\overline{D} = \int_{D_{min}}^{D_{max}} Df(D)dD$, and

the cost, C_W, of electricity from the wind-powered plant obeys the function

$$C_W = C_o e^{-\frac{(G-20)}{180}}, \text{ where}$$

C_o = 20 ¢/kWhr.

C. Assuming that both the coal-fired and oil-fired plants are always capable of providing their respective full outputs, what fraction of the time during a year would the oil-fired plant be used?

Note: $\text{Prob.}(D < d) = \int_{D_{min}}^{d} f(D)dD.$

3. Using the Monte Carlo calculator located on the Sustainable Energy website, consider the contributions of three different coal producing regions to their total ultimate production. The Monte Carlo simulator is an executable located at the bottom of the **Assignments** page at the link **Monte Carlo for Windows**. The next link, **Read Me**, will be helpful for installing and running the simulator.

- Region 1: f(P1) is uniformly distributed within the range 50 MT < P1 ≤ 100 MT, where P1 is the ultimate production from Region 1.
- Region 2: f(P2) is symmetrically triangularly distributed within the range 100 MT < P2 ≤ 200 MT, where P2 is the ultimate production from Region 2.

  Note: Recall that $\int_{P2_{min}}^{P2_{max}} f(P2)d(P2) = 1$, normalization.

- Region 3: f(P3) is truncated-normally distributed within the range 50 MT < P3 ≤ 150 MT, where P3 is the ultimate production from Region 3, and the mean, μ, of the distribution = 100 MT, and the standard deviation, s, of the distribution = 10 MT.

Using 1,000 samples of each field, what are the approximate values of the following:

A. The expected (i.e., mean) total ultimate production, $\overline{P}$, from all three regions.

Note: $\overline{P} = E(P) = \int_{P_{min}}^{P_{max}} P \cdot f(P) dD$, and

$f(P_i) \approx \frac{N(P_i)}{N_{total}}$, where

$N(P_i)$ = number of cases where P_i lies within the range

$\left(P_i - \frac{\Delta P_i}{2}, P_i + \frac{\Delta P_i}{2}\right)$ for a defined discrete interval ΔP_i, and

$N_{total} = \sum_{i=1}^{m} N(P_i)$.

B. The probability that the total ultimate production from all three regions will exceed 400 MT.