NATIONAL UNIVERSITY OF SINGAPORE Department of Electrical Engineering

EE4511 RENEWABLE GENERATION AND SMART GRID
Tutorial 3

1. In a small hydro system, 5600 litres per minute of water is drawn from a river and delivered through a 250 m long 4-inch diameter pipe to a turbine located 30 meters lower than the source. Calculate the power delivered by the turbine generator if the pipe loses 5% head due to frictional losses. Assume the turbine-generator efficiency to be 80%.

2. A hydroelectric system consists of a large dam with an effective height of 205 metres. The rated generating capacity for the power plant at the dam is 1 GW, the frictional losses in the 300 metre long penstock are 2%, and the turbine-generator efficiency is 95%.
   (i) At maximum capacity, what flow is required through the dam's turbines to generate its rated power?
   (ii) If the dam operates at 60% of capacity on average, how much energy does it produce in a year?
   (iii) How many people should this energy support, assuming average community consumption of 2500 kWh per year per person?

3. Suppose 750 litres per minute of water is taken from a creek and delivered through 220 meters of 3-inch diameter PVC pipe to a turbine 40 meters lower than the source. If the turbine/generator has an efficiency of 40%, find the electrical power that would be delivered. In a 30-day month, how much energy would be provided?

4. The Glen Canyon Dam in Arizona dams the Colorado River creating Lake Powell behind it. Total nameplate (maximum continuous) generating capacity for the power plant at the dam is about 1 GW. Assume an effective head of 200 meters and generating efficiency of 95%.

   (i) At maximum capacity, what flow is required through the dam's turbines to generate its nameplate power? Express flow in cubic meters.
   (ii) If the dam operates at 60% of capacity on average, how much energy does it produce in a year?
   (iii) How many people should this energy support, assuming average community consumption of 3000 kWh per year per person?

   (iv) (*for further investigation*) How much coal would be required in a coal-burning power plant to generate the equivalent amount of energy as the Glen Canyon Dam generates in a year? Assume that the dam generates 5 billion kWh hours (5×10^9 kWh or 5 terra-watt hours) of energy annually.
   - The energy content of coal is 8,142 kWh/tonne
   - The energy efficiency of a typical coal-burning power plant is about 38%

5. Determine the best combination of hydropower plants for an investment in a hydroelectric project using cost-benefit analysis. Hydropower plants of various and corresponding benefits are shown in the table below.

   Determine the combinations of hydropower plants which can maximize the benefits while satisfying the 395 MW generation capacity requirement.
   The budget for the investment is limited to $ 110 million.

   (Note: there can be more than one right answer to this question)

Table 1. Hydropower Project Data

Scale (MW)	Benefits B ($ mln)	Costs C ($ mln)	Net Benefits *B - C* ($ mln)
50	18.0	15.0	3.0
60	21.0	17.4	3.6
75	26.7	21.0	5.7
90	29.8	23.4	6.4
100	32.7	26.0	6.7
125	38.5	32.5	6.0
150	42.5	37.5	5.0
200	50.0	50.0	0.0